THE

JOURNAL

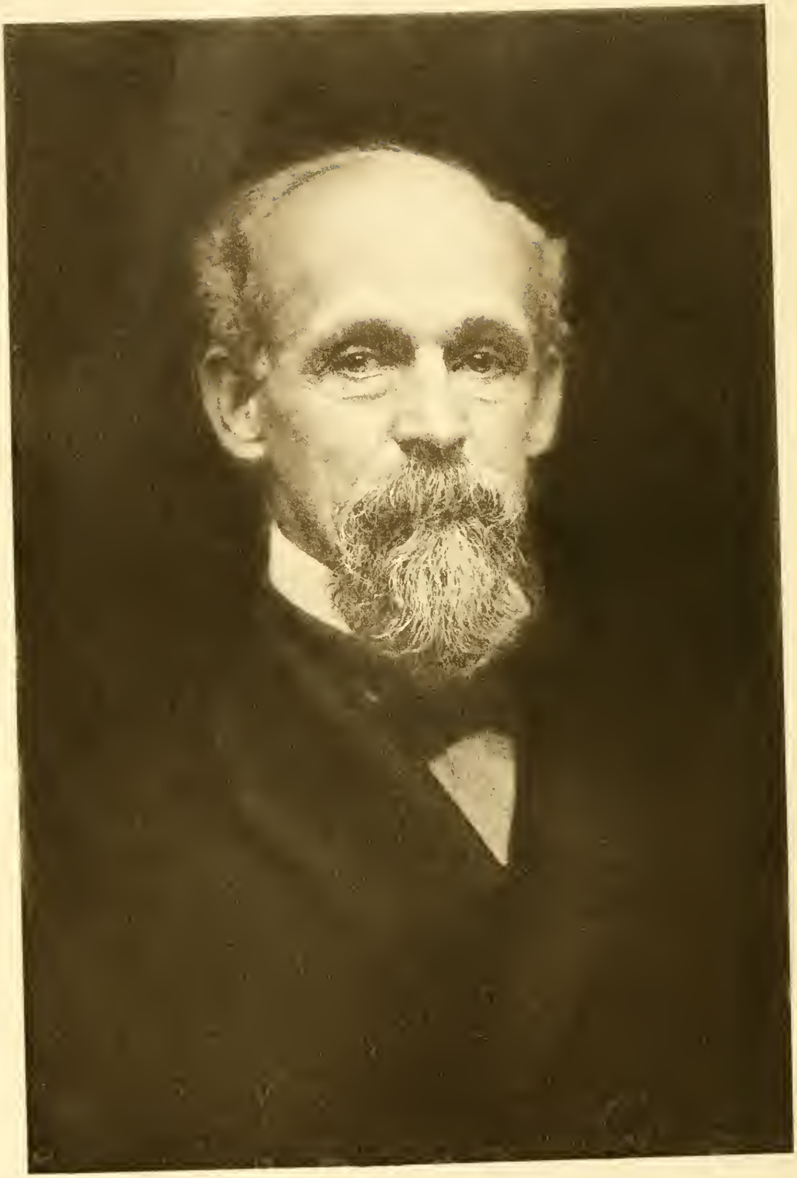
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
29 W. 39 ST., N.Y.

JANUARY 1909

NEXT MONTHLY MEETING JANUARY 12



Jno A Brashear

HONORARY MEMBER

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JANUARY 1909 VOL. 31 No. 1

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

WITH SUPPLEMENT

PUBLISHED AT 2427 YORK ROAD - - - - BALTIMORE, MD.
EDITORIAL ROOMS, 29 W. 39TH STREET - - - - NEW YORK

CONTENTS

THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.
Price, one dollar per copy—fifty cents per copy to members. Yearly subscription, $7.50; to members, $5.
Application filed for entry at the Postoffice, Baltimore, Md., as second-class mail matter under the act of March 3, 1879

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 JANUARY 1909 NUMBER 1

THE next monthly meeting will be held in the Engineering Societies Building on Tuesday evening, January 12. The paper will be by Carl G. Barth, Consulting Engineer, Philadelphia, Pa., upon The Transmission of Power by Leather Belting.

This will be one of the most comprehensive presentations of the subject of belting that has been given before the Society. The author has coöperated, during a period of 18 years, in the use of belting in manufacturing plants and especially machine shops where systems of management have been installed involving the scientific operation of machine tools. This has necessitated a careful study of the whole belting problem, both theoretically and practically, and has led to important conclusions which are given by the author in his paper. There has been ample opportunity to compare these conclusions with the results obtained in actual practice.

The theory which Mr. Barth has deduced is based on the well known experiments of Lewis and Bancroft and other members of the Society who have investigated different factors of the belting problem and his paper is, therefore, a summing up of the various points connected with the transmission of power by belting, a subject which has been in more or less of an unfinished or uncertain state.

The paper is published in this number of The Journal and contains valuable charts to assist in the solution of belting problems. Mr. Barth will use lantern slides to illustrate his paper. It is urged that any who have the results of practical experience to offer attend the meeting and contribute to the discussion.

THE ANNUAL MEETING

The twenty-ninth annual meeting of The American Society of Mechanical Engineers was held in the Engineering Societies Building December 1–4, with an attendance of 738 members, the largest in the history of the Society, and a total registration of 1048. This total is not as high as that of a year ago, but it actually represents a larger attendance since this year only those were registered as guests who were to participate in the social functions.

The meeting was noteworthy in several particulars. There were six professional sessions, one more than at any previous convention. One of these was a machine shop session which led to the first steps being taken toward the formation of a machine shop section. The subject of aëronautics was considered for the first time by an American national engineering society. On Tuesday evening, besides the President's address was the conferring of honorary membership upon Dr. John A. Brashear, followed by his delightful lecture upon A Journey Among the Stars. On Thursday evening was the intensely interesting lecture by Lieut. Frank P. Lahm on The Conquest of the Air.

OPENING SESSION, TUESDAY EVENING

The opening session of the convention is always an anticipated occasion. It is a social event where members first greet one another and is, moreover, the time for the delivery of the annual address of the President.

The session was called together by President M. L. Holman, who proceeded at once with his address. In view of the activity of the Society in the conservation movement and the participation by President Holman in the governors' meeting at Washington, his subject was very properly The Conservation Idea as Applied to The American Society of Mechanical Engineers. The address is printed in full in this number. It considers broadly questions related to the conservation of our resources, including health, food, land, forests, water and water power, coal and steam power, minerals, etc. It is held that the crucial test of the work of the engineer will be

found in the cost per unit of output and will be measured by the ability of the work designed by him to compete in markets of the world. He is interested as one of the producing class in the conservation of the materials of the country and likewise in the conservation of the results of his own labor. Engineering societies also must see that their returns are commensurate with the efforts expended.

Following the address, Mr. W. R. Warner, Chairman of the Committee appointed for the purpose, presented Dr. John A. Brashear for honorary membership, saying:

It is my privilege to present John Alfred Brashear, Sc.D., LL.D., F.R.A.S., Member of the Astronomical Societies of Great Britain, France and Belgium and of the American Philosophical Society; Past Chancellor of the University of Western Pennsylvania; Organizer of Carnegie Institute; Collaborator with Langley in devising and making the bolometer for measuring heat to 1/100 000 of a degree; Co-worker with Morley and Michaelson in constructing the interferometer which established wave lengths of light as the unit of linear measure; Maker of Astronomical Instruments of unequaled delicacy and precision, the spectroscope whereby Keeler discovered the constitution of Saturn's rings and Campbell the motion of the stars in the line of sight, and the spectroheliograph with which Hale has determined the constitution of the sun and analyzed its elements; Physicist, Astronomer, Educator, whose contributions to science and technical learning are surpassed in value only by his personal worth and greatness of soul, which have endeared him to all who know him.

Dr. Brashear is thus formally presented in order that he may receive from you the certificate of honorary membership in The American Society of Mechanical Engineers.

The President then replied: John Alfred Brashear, Eminent Engineer, Scientist, Astronomer, Educator, and Craftsman, the Society is proud to honor you with the distinction I am now to confer. The mechanical engineering profession recognizes your achievements in the production of parts of optical apparatus whose mechanical perfection has never been approached, and which it will be difficult to surpass. For these reasons, by the authority conferred upon me, I now advise you that you have been elected to Honorary Membership in The American Society of Mechanical Engineers, and to all the rights and privileges attaching to this distinction.

In Witness Whereof, will you accept at our hands the diploma of such membership.

Dr. Brashear had been invited to address the Society on A Journey Among the Stars, and his lecture followed. By way of introduction he said that no honor which had been conferred upon him came so close as that just given—an honor by men who know the worth of real work. There is something that draws men to one another which is elevating and ennobling to the man who loves his work for its own

sake. He said, "There is a beautiful adage that I learned long ago· It goes this way: 'What man is there, who, coming in contact with great souls, is not made happier and better thereby.' A drop of water on the leaf of a lotus glitters with the luster of a pearl. And so our deeds may be small, if they are only done in the right spirit."

The speaker then took his audience on a journey made possible only by the wonderful developments of stellar photography, since the camera alone can penetrate the universe and the infinite spaces beyond. The photographs which Dr. Brashear displayed appeared as wonderful as those shown by him at Detroit at the time of the Spring Meeting. Striking features of the lecture were the illustrations used to indicate the magnitude of the heavens and to show how the movement of stars is determined by means of the spectrum.

BUSINESS MEETING

On Wednesday morning was the annual business meeting and the first professional session. President Holman called the meeting to order and reminded those present that in view of the large number of papers to be presented at the various sessions, it might be necessary for the Chair to limit discussions upon papers to the time specified by the rules. He suggested, however, that as there were eight auditoriums in the building, it would be possible to hold simultaneous meetings if any considerable number of members desired to continue the discussion upon a given topic beyond the time alloted. This plan was actually carried out in order to extend the discussion upon the papers given on the following morning upon machine shop subjects. On the afternoon of that day there were three sessions in progress at one time.

The first order of business was the reading of the report of the Tellers of Election. There were 179 applicants for membership and 21 for advance in grade. These having been duly balloted for were declared elected and the names are to be published in the membership list of The Journal.

The following officers were declared elected for the succeeding year: President, Mr. Jesse M. Smith; Vice-Presidents, Mr. Geo. M. Bond, Prof. R. C. Carpenter, Mr. F. M. Whyte; Managers, Mr. H. L. Gantt, Mr. Will J. Sando, Mr. I. E. Moultrop; Treasurer, Maj. Wm. H. Wiley.

The newly elected President, Mr. Jesse M. Smith, was then escorted to the Chair and spoke briefly as follows:

The honor which you have conferred upon me I sincerely appreciate. I recognize also the great responsibility that comes with the honor. The influence of the Society in the advancement of engineering, must not only be maintained, but greatly extended. It will be my endeavor to conserve the best traditions of the Society and to aid in its taking a position still farther forward.

Were I to follow precedent I would say no more at this time; but there is a subject which seems to me of great importance to the future of the Society, which I would like briefly to call to your attention.

The prominent new feature of the constitution, under which the Society has been operating for 5 years, is the formation of standing committees to foster, organize and direct its various activities. Each of these seven committees is composed of five members. One member retires at the end of each year and a new member is appointed by the President. Thus the committees, while permanent as organizations, are being constantly and automatically renewed as to personnel.

The Secretary of the Society is the secretary to the Council and also the secretary to each of the standing committees. Thus the membership, the Council, and the various committees are properly coördinated to work together in harmony for the advancement of the Society; each committee taking charge of, and being responsible for, the particular work assigned to it by the constitution. The function of each standing committee is to initiate, promote and organize the work given to it by the constitution and by-laws, subject to the approval of the Council.

It is evident that when all the committees are in full operation, the Secretary as the executive officer will be fully occupied in carrying out the various activities initiated and organized by these various standing committees. The Secretary should not be called upon to do work which properly belongs to the Committees, however willing he may be to do so.

The orderly and systematic work of the Secretary is of the greatest importance. Through the good work of his office, the membership, scattered over the world, receives prompt, accurate and full information of what the Society is doing for the advancement of engineering.

Great and important and good as may be the work of the Secretary, there is a greater and different work to be done by the standing committees; and it is their active work which will inspire greater activity among the membership of the Society.

These committees, when fully organized, will contain 35 men who should be selected from the membership because of their peculiar qualifications and fitness to do the special work required. They must be men who can and are willing to devote the necessary time to the work. These 35 men are officially called to places of honor. They should, and undoubtedly will, respond to the call with ardor, and with the determination to "set the pace" for the membership at large in the march forward. The success and influence of the Society should be in direct proportion to the number of men who are active in its welfare.

The good work of the standing committees is already well commenced, but it should be extended and expanded, and improved with the experience of years and by the infusion of new and young blood until each committee accomplishes its full function.

The best work done in the Society has been done by men inspired with love for the profession of engineering. Love for the Profession does not die. There are now, and always will be, in this Society men who are thus inspired. Let them

come forward and take up the work before them, or if they be diffident, let us seek them out and bring them forward.

Let the members of the committees bring their work up to such a high degree of excellence and efficiency, that a position on a standing committee of The American Society of Mechanical Engineers will be an honor which a rising engineer, who loves his profession, will wish to attain.

FIRST PROFESSIONAL PAPERS

After the remarks by the President-elect, came the two professional papers of the morning, the first one being The Engineer and the People—a Plan for a Larger Measure of Coöperation Between the Society and the General Public, by Morris Llewellyn Cooke, Philadelphia, Pa. This paper advocates a more direct interest by engineers in affairs affecting the public and a greater effort to enlighten the public as to the advantages and achievements of engineering. A corresponding change is already in progress in other professions which the engineering profession may well emulate. The author asked for the appointment of a standing committee to be known as the Committee on Relations with the Public.

This paper was largely discussed both by members of the Society and prominent men identified with other lines of activity. Among the latter who contributed written discussions were: Arthur T. Hadley, LL.D., President of Yale University; Talcott Williams, LL.D., Associate Editor, Philadelphia Press; Frank Miles Day, Architect; Hon. Geo. W. Guthrie, Mayor of Pittsburg; Arthur L. Church, Trustee of the University of Pennsylvania.

Mr. Ambrose Swasey offered the following resolution, which was seconded by Mr. Fred W. Taylor:

Resolved: That we recommend to the Council the appointment of a professional committee to advocate, consider and report on the methods whereby the Society may more directly coöperate with the public on engineering matters and on the general policy which should condone such coöperation.

The resolution was unanimously carried.

Prof. F. R. Hutton called attention, in connection with the recommendation of Mr. Cooke that a Committee on Relations with the Public should be created, that this would require an amendment to the Constitution. He therefore gave notice of the purpose to make such an amendment in accordance with the provision of she Constitution to Article C45 at the Spring meeting, at which such amendment can come up for discussion.

The second paper of the morning was by Major Geo. O. Squier

of the Signal Corps, U. S. A., on the Present Status of Military Aëronautics. This paper with its illustrations was published in full in the last number of The Journal and is a remarkably complete statement of the development of the leading types of air craft. It deals to a certain extent with the problems of design and gives dimensions of different dirigible balloons and aëroplanes, besides data upon the construction of these types of machines.

The paper was discussed by Dr. W. J. Humphreys of the Weather Bureau, who told about the relation of the winds to the problems of flying machines. Dr. John A. Brashear spoke feelingly of the early work of Professor Langley in the development of the aëroplane, and of the credit due to him for his accomplishments. He was followed by Geo. L. Fowler, who had been associated with Professor Langley and he gave a brief sketch of some of his interesting work.

WEDNESDAY AFTERNOON SESSION

The meeting was called to order by President Holman who requested Mr. Geo. R. Stetson to preside.

The first paper was upon A Method of Obtaining Ratios of Specific Heat of Vapors, by A. R. Dodge of Schenectady, N. Y. This outlines a method of obtaining the ratio of specific heat which does not involve the use of available steam tables nor a condition in which the steam is presumed to be without moisture or superheat. Tables of data are included. The paper was discussed by Dr. Harvey N. Davis, who said he had an opportunity to go over the data previous to the presentation of the paper in connection with some of his own work and believed the method of using the throttling calorimeter which Mr. Dodge had devised was a great advantage in technique in the measuring of superheat.

The next paper was by Dr. Harvey N. Davis, Cambridge, Mass., upon The Total Heat of Saturated Steam. It has, for some time, been suggested that Regnault's formula for the total heat of saturated steam is considerably in error. This conclusion is confirmed by computing the value from the results of various experimenters upon the specific heat of superheated steam. From their work Dr. Davis has deduced a formula which is believed to give much more accurate results. The paper was discussed by Prof. C. H. Peabody, Prof. R. C. H. Heck, Prof. Wm. D. Ennis. There was a contributed discussion by Prof. Lionel S. Marks.

Following these papers upon what may properly be classed as

engineering physics dealing with the refinements of engineering, were two papers by Mr. C. R. Weymouth of San Francisco, Cal., presenting important results in the line of engineering practice. These were presented for the author by Prof. D. S. Jacobus. The subjects were Fuel Economy Tests at a Large Oil Burning Electric Plant and Unnecessary Losses in Firing Fuel Oil. The first of these contains results of tests upon a 15 000 kw. power plant of the Pacific Light and Power Co., Redondo, Cal., having steam engine prime movers and using crude oil as fuel. The results were given for various uniform loads, ranging from 2000 to 5000 kw.; also for the entire station on a variable railway load.

The second paper describes apparatus for securing proper adjustments in automatic firing for steam boilers in plants burning liquid fuel. The paper also has valuable data upon the heat value of California oils.

These two papers were discussed by Prof. Wm. Kent, Prof. Wm. D. Ennis, J. R. Bibbins, I. E. Moultrop, A. H. Kreusi, Prof. I. N. Hollis, and by Geo. H. Barrus with a contributed discussion.

WEDNESDAY EVENING LECTURE

On Wednesday evening was the lecture on aëronautics by Lieut. Frank P. Lahm of the Signal Corps, U. S. Army, who took as his subject The Conquest of the Air. The interest aroused by this feature of the annual meeting is indicated by the size of the audience which greeted the speaker. It was the largest in the history of the Engineering Societies' Building. Every seat and the available standing room of the auditorium were taken and the evident anticipation of the audience changed to enthusiasm as the speaker skilfully developed his subject.

The lecture was illustrated by a profusion of lantern slides and by motion pictures of dirigible balloons and the Wright Brothers' aëroplane. The speaker traced the important events related to the development of air ships during the past 125 years, beginning with the discovery in France of the principle of the hot-air balloon by the Montgolfier brothers. Benjamin Franklin witnessed one of the earliest ascensions in France by hot-air balloon and is reported to have had faith in this type of craft. In reply to the question "Of what use are balloons?" he said "Of what use is a new-born babe?"

Lieutenant Lahm is an experienced balloonist and his graphic description of a balloon ascension was so evidently a recital of his own experiences as to add force to his remarks. He described the

process of preparing a balloon for ascension and inflating it and the instruments used by the aëronaut. To maintain equilibrium when a balloon is in the air requires close attention. A cloud passing across the sun cools the gas and starts the balloon down, or a burst of sunshine on a cloudy day produces the opposite effect. The cool air encountered in passing over a forest has the same effect as the cloud. The pilot must know at once when his balloon starts up or down. A little sand thrown out at the beginning of a descent will do more to stop it than a large quantity later. The registering barometer does not record quickly enough, so an aneroid barometer with a circular dial and a needle is used; or more often a statoscope, which indicates instantly whether a balloon is going up or down. A sextant with artificial horizon is used for finding the latitude of a balloon when above the clouds.

Answering the questions that are commonly asked about ballooning, the speaker said there is nothing by which one can measure his height, and there is no unpleasant motion as in an elevator. Suspended in the air and moving with it, one does not realize that he is moving at all. There is therefore no unpleasant sensation; the delights of ballooning can be realized in no other way; and at the conclusion of a trip the landing is made, the balloon shipped back to the starting point by freight or express, and "its passengers settle down comfortably to their dinner in the dining car and go over again the enjoyable incidents of the ascension."

Interest in aëronautics was greatly stimulated by the international competition for the Gordon Bennett Cup in 1906. This race was from Paris and was won, the speaker modestly said, by "an American." This race was with free balloons, but it is expected that dirigibles will enter future races.

Descriptions were given of representative dirigible balloons, beginning with that of Santos Dumont in 1898, who succeeded three years later in circling the Eiffel Tower in his balloon. Another early and successful airship was that built by the Frenchman Julliot, an engineer in the employ of Lebaudy brothers, wealthy sugar refiners in Paris, who backed him. His efforts finally led to the construction of the well-known *Patrie.* Many views were shown of the familiar war balloons of the various countries, including the *République, Ville de Parie, Gross, Parseval, Zeppelin* and the dirigibles of the British and American armies which bear numbers only in place of names.

Of greater interest than any of these, perhaps, was the account of

the Wellman airship designed for reaching the North Pole. It was built in Paris in 1906 and transported to Spitzburgen. It was designed as a weight carrier, with a speed of only 15 miles an hour, and would carry a crew of three men, dogs, sleds, boat, and abundant provisions. By taking advantage of favorable winds it was hoped to cover the 700 miles to the pole in two days. The return journey would be less difficult as any direction would lead back to civilization. In attempting its flight, however, bearings were lost and the ship had to be returned to its quarters.

In dealing with heavier-than-air machines prominence was given to the work of the Wright brothers, whose aëroplane at Fort Myer, Va., established so notable a record. Proper recognition was also given to the early work of Prof. Langley who, in 1896, constructed a model that flew a mile under steam power.

The culminating feature of the lecture was the moving pictures. Huge dirigible balloons were seen slowly moving out of their balloon houses and later returning. The Baldwin dirigible was shown in actual flight and then there were views of the rapidly moving Wright brothers' machine, which flitted across the screen like a great bird.

In conclusion the speaker said, "With dirigible balloons capable or remaining in the air 13 hours, covering a distance of 176 miles; with the Wright aëroplane which has already remained in the air an hour and a half and has carried two persons at the rate of 40 miles an hour, under the perfect control of its operator, I think it will be agreed that the experimental stage is past and the conquest of the air is a fact."

THURSDAY MORNING—MACHINE SHOP SESSION

The session on Thursday morning was devoted to papers upon machine shop practice. Vice-President Fred J. Miller presided.

The first paper was upon Efficiency Tests of Milling Machines and Milling Cutters, by A. L. DeLeeuw, Cincinnati, O. It pointed out the desirability of indicating the power of a machine tool by the amount of metal which it is capable of removing, rather than by the size of the driving pulley and belt. It described tests upon several milling machines for the purpose of ascertaining the amount of metal removed and the capacity; also the horsepower required under various conditions of feed and speed. It considered the mechanical efficiency of the machines and gave results of tests showing the importance of improvement in milling cutters.

The paper was discussed at length by Wilfred Lewis, who presented a discussion for himself and Wm. H. Taylor; by Fred J. Miller and Fred W. Taylor. There were discussions, also, by Prof. H. W. Hibbard and Prof. J. J. Flather.

The next paper was upon the Development of the High Speed Milling Cutter with Inserted Blades for High Speed Steel, by Wilfred Lewis and Wm. H. Taylor, both of Philadelphia, Pa. The milling cutter which formed the basis of this paper has inserted helical blades of high speed steel, mounted in a steel holder to give a solid backing for the blades on the driving side against which they are held by a soft metal filler on the opposite side. The cutting power of a cutter built up in this way is so great that it is stated to be beyond the capacity of any milling machine now on the market. Tables of results of tests were included in the paper. The discussion was by Fred J. Miller, Oberlin Smith, Fred W. Taylor, A. L. DeLeeuw, A. D. Carhart, Prof. R. T. Stewart, Webb J. Burkitt and Harrington Emerson.

Following these papers upon milling practice was one upon lathe tools by James Hartness, Springfield, Vt., entitled Metal Cutting Tools without Clearance. The tool operates on a new principle developed by the author which, contrary to the universal plan of cutting tools, was designed to be used without clearance. The tool is supported in a holder so constructed as to allow a slight oscillatory motion which permits the face of the tool to bear against the face of the metal from which the chip is being cut. This steadies the tool, prevents lateral vibration which is detrimental to the cutting edge of any tool and so permits a more acute cutting edge.

In presenting the paper, Mr. Hartness prefaced the reading by remarks upon the use of lubricants, stating that it was necessary in certain cutting operations to use lard oil. The paper was discussed by Henry Harrison Suplee who mentioned that he had used wood cutting tools without clearance in planing machines for much the same purpose as Mr. Hartness used his metal cutting tool without clearance. The objection for that class of work, however, had been the heating of the cutting edges.

The last two papers were upon the subject of gearing which in this instance, as in times past, proved to be most prolific of discussion. The first paper entitled Interchangeable Involute Gear Tooth Systems, by Ralph E. Flanders of New York, showed the effect of varying the pressure angle and height of addendum on the various practical qualities of gearing, such as continuous action, side pressure, strength,

efficiency, etc. The author asked that the question be discussed of a Committee to investigate and report to the Society on the wisdom of an alternative form of gearing for heavy use. The first discussion was by Wilfred Lewis, who advocated the investigation of the subject and made the following motion:

"I would therefore propose that this subject be referred, as Mr. Flanders suggested, to a committee of this Society to investigate and report upon the adoption of a standard system of involute gearing. The paper covers the case from a 12-tooth pinion to a rack. That is as far as I would go with such a system. If internal gears are employed, that would be understood to be more or less special."

This paper was very much discussed, the following contributing discussions: Wilfred Lewis, Luther D. Burlingame, D. F. Nisbet, Chas. W. Hunt, Oberlin Smith, Prof. F. R. Hutton, Prof. F. de R. Furman, A. L. DeLeeuw, Elmer H. Neff. There were also contributed discussions by Lewis Sanders, E. R. Fellows, John C. Fawcus, Frank Burgess.

The second paper upon gearing was upon Spur Gearing on Heavy Railway Motor Equipments, by Norman Litchfield, New York. This dealt with the breakage of gearing in heavy electric railway service and referred to the work of the Interborough Rapid Transit Co. in overcoming this difficulty. It considered the materials and design of gearing for heavy duty including the shape of tooth outlines employed. The discussion upon Mr. Litchfield's paper was all written, submitted by the following: F. V. Henshaw, John Thomson, J. Kissick, Jr., Geo. W. Sargent, Prof. F. de R. Furman.

The discussion upon the gearing papers was so extended that the session adjourned until afternoon, at which time Prof W. Rautenstrauch presided.

At this session the resolution offered by Mr. Lewis in the morning calling for the appointment of a committee to consider the matter of interchangeable involute gearing was brought up and unanimously carried. In order to conform to the usual procedure in such matters it was suggested by Mr. Elmer H. Neff that the resolution should be in the form of a request to the Council to take up the matter, which was concurred in by Mr. Lewis.

THURSDAY AFTERNOON SESSION

Prof. F. R. Hutton, who acted as Chairman, announced that the paper by Mr. Mellin upon Articulated Compound Locomotives would

be deferred until later in the afternoon when the lantern slides would be more effective.

The first paper to be presented was upon Liquid Tachometers, by Amasa Trowbridge, Hartford, Conn. This described the Veeder liquid tachometer and methods used in testing and calibrating it. It was discussed by H. H. Wait and H. G. Reist.

The next paper, by H. L. Gantt, Pawtucket, R. I., upon Training Workmen in Habits of Industry and Coöperation, drew out the most active discussion of any paper of the convention. It emphasized the fact that with the advent of the scientifically educated engineer capable of substituting a scientific solution of problems for the empirical solution of the mechanic, the responsibility of training workers actually shifts to his shoulders. If he properly conducts this training along the lines of scientific investigation efficiency of the workmen can be so greatly increased that the employer can afford to pay far in excess of the compensation usually allowed.

The discussion was very favorable to the contentions of Mr. Gantt, the idea being expressed that they represented humanitarian ideas rather than the purely commercial aspect so often predominating in the training of workmen. Oral or written discussions were contributed by the following: Dr. Rudolph Roesler, W. E. Hall, Charles Piez, Lewis Sanders, H. V. R. Scheel, H. K. Hathaway, T. Kelly, C. N. Lauer, J. C. Jurgensen, Harrington Emerson, Milton P. Higgins, Prof. Wm. Kent, Albert H. Emery, Jas. M. Dodge, Frank A. Haughton, C. H. Buckley.

Geo. B. Willcox of Saginaw, Mich., next presented a paper on Salt Manufacture, in which he described apparatus used in the manufacture of salt by the grainer process including the design of evaporated grainers built of reinforced concrete, and devices for handling and conveying salt and loading salt barrels into cars. There was a contributed discussion by C. F. Hutchings.

The next paper, upon Industrial Photography, by S. Ashton Hand, Cleveland, O., was illustrated by lantern slides showing some remarkably perfect results obtained in photographing machinery and interior of shops. These illustrated methods used by the author in bringing out details and avoiding shadows or too prominent high lights. He showed by a series of plates results that could be obtained in developing plates that were under or over-exposed; the effect of different lengths of exposure upon plates and how certain defects in plates could be remedied. This was discussed by the following: C. J. H. Woodbury, Henry T. Binsse, Charles W. Hunt, H. H. Suplee, Ambrose Swasey.

The paper upon Articulated Compound Locomotives by C. J. Mellin, Schenectady, New York, which had been deferred until the end of the meeting, described locomotives articulated by the Mallet method by means of which the tractive power can be doubled over that of an ordinary engine for a given weight of rail with a substantial saving in fuel. A very full discussion of the paper was offered by F. J. Cole, and S. M. Vauclain presented a discussion illustrated by a number of lantern slides. Other discussions were offered by Harrington Emerson, L. R. Pomeroy, Geo. L. Fowler, Geo. R. Henderson, Alfred Lovell.

GAS POWER MEETING

The Gas Power Section held a meeting on Thursday afternoon, Dr. Charles E. Lucke in the chair, and about 150 members of the section present.

The executive committee of the section reported that it had proceeded to the election of officers for the ensuing year, as follows:

Chairman, F. R. Low; Secretary, George A. Orrok; Chairman of the Membership Committee, Robert T. Lozier; Chairman of the Meetings Committee, Cecil P. Poole; Executive Committee, F. H. Stillman, George I. Rockwood, R. H. Fernald, F. R. Hutton, H. H. Suplee.

The retiring executive committee recommended the appointment of a nominating committee, to place at least two candidates in nomination for each office; a committee on installations, to keep up a list of all power plants; and giving complete data as to equipment; a committee on plant operation, to collect information as to load characteristics, costs of operation, behavior of apparatus, etc., and a committee on breakdowns, failures, etc., to collect and file information as to accidents, unsatisfactory operation, etc.

In connection with the work of the standardization committee a communication from Professor Lionel S. Marks was presented by Professor Ira S. Hollis, discussing the high and low heat values, and calling attention to the fact that the "effective" heat value in German practice is the heat value of the gas under the conditions of temperature and pressure at which it is used.

An interesting paper was presented by Mr. L. H. Nash, reviewing his own experiences in gas-engine work, and showing the extent to which old ideas have cropped up from time to time. This paper, which was profusely illustrated by lantern slides, was most interest-

ing and instructive. A paper upon Some Possibilities of the Gasolene Turbine, by Prof. Frank C. Wagner, was read in abstract, in the absence of the author. This paper discussed analytically the relative effects of an excess of air, or an injection of water for keeping down the temperature of the gases.

Dr. Lucke called attention to the observed facts as to the behavior of the free expansion of gases in nozzles, showing that assumed effects are not realized in practice, and recommended further experimentation in this direction.

THURSDAY EVENING RECEPTION

On Thursday evening was the Annual reception which this year was held in the rooms of the Society, and followed by the collation on the sixth floor and dancing on the seventh floor of the Engineering Societies Building.

FRIDAY MORNING SESSION

The papers for Friday morning presented mainly the results of tests upon various types of apparatus. The first by Prof. R. T. Stewart of Pittsburg, Pa., was one of a series of papers which he has read before this Society upon extended lines of investigation which he has conducted. This paper dealt with the Physical Properties of Carbonic Acid and the Conditions of its Economic Storage for Transportation. It treated exhaustively of the physical properties of carbonic acid, and mentioned tables of data heretofore unavailable. There was also a discussion of the design of cylinders to withstand high pressures. The discussion on the paper was, from the nature of the subject, somewhat out of the sphere of mechanical engineering and bore largely upon the safety of carbonic acid cylinders used for the storage transportation of a chemical. The following offered discussions: John C. Minor, Jr., H. E. Sturcke, Graham Clarke, L. H. Thullen, E. D. Meier, Sanford A. Moss.

The Slipping Point of Rolled Boiler Tube Joints, by Professors O. P. Hood and G. L. Christensen, Houghton, Mich., was the title of the next paper which had for its object the recording of data regarding the behavior of joints made by rolling boiler tubes into the containing holes of the tube sheets. Discussion was offered by J. C. Parker, C. H. Benjamin, E. D. Meier, M. W. Sewall, F. W. O'Neil.

The third paper by Prof. R. G. Dukes on Tests on Friction Clutches for Power Transmission gave results of tests upon friction clutches

of different makes and was discussed by the following: Geo. N. Van Derhoef, P. E. Welton.

The final paper of the morning was a brief description with the theory of the design of An Averaging Instrument for Polar Diagrams, by Prof. W. F. Durand, Stanford University, Cal. It was intended to supply information for the design of the planimeter for use on polar diagrams so commonly used on different types of recording instruments.

The meeting closed with the following resolutions:

WHEREAS: The American Society of Mechanical Engineers at their Annual Meeting, December, 1908, desires to express its appreciation to those who have provided opportunities for entertainment; and on behalf of its visiting members thanks for the welcome so cordially given by the local members and their friends of New York and vicinity.

Be it Resolved, that the Secretary be instructed to extend the thanks of the Society and to express the appreciation of its members and guests to the local committees for their untiring efforts; to those who have sent invitations to visit engineering works and places of interest; to Professor Brashear for his delightful lecture; to Brig. Gen. James Allen and his associates of the Signal Corps for the remarkable presentation of Aëronautics before the Society; and especially to the ladies who extended so generous a hospitality to their guests.

THE NEW PRESIDENT OF THE A. S. M. E.

Mr. Jesse M. Smith, the President of the Society for 1909, was born in Newark, Ohio, in 1848. He moved to Detroit, Michigan, with his father's family in 1862. In 1865 he entered Rensselaer Polytechnic Institute, Troy, New York, remaining there three years. The following year he spent traveling in Europe, and entered L'École Centrale des Arts et Manufactures, Paris, France, receiving the degree of M.E. in 1872. During his vacations, he traveled among the manufacturing plants of France, Germany and Belgium and attended lectures in the Polytechnic Institute in Berlin. After graduation in Paris he traveled three months among the iron and machine works of England.

He began the practice of engineering in 1873, designing and superintending the erection of blast furnaces for smelting iron from native ores with raw bituminous coal in the Hocking Valley, Ohio. He made surveys of coal mines, opened mines and built coal handling machinery for them. He surveyed and constructed railroads from mines to furnaces.

Upon the death of his father, in 1880, Mr. Smith returned to Detroit and opened an office as Consulting Engineer. He designed and constructed a high speed center crank steam engine with shaft governor,

containing the feature of the modern inertia weight governor, and put it in operation driving a Brush dynamo producing 40 arc lights in 1883, and in 1890 he presented a paper before the Society on this governor.

He represented the United States Electric Lighting Company in Ohio and Michigan 1884 to 1886—during which time he erected a number of the early incandescent electric light plants, including one of 1000-light in the Stillman Hotel, Cleveland, Ohio, which was the first hotel lighted exclusively and continuously by electricity from its own plants. He returned to the work of Consulting Engineer in 1886 and continued in it until 1898. During this time he designed and erected several power plants and several plants for electric lighting and electric railways; also apparatus for steam heating with exhaust steam in several large manufacturing plants.

He began in 1883 to be called as an expert witness in the U. S. Courts in patent litigation. This practice gradually grew and displaced the work of consulting engineer until 1898, when he moved to New York to continue the practice of expert in patent causes exclusively.

Among the notable cases in which he acted as expert were: steam injectors under the Hancock Inspirator patents; cylinder lubricators for locomotives; roller mills and middlings purifiers for flour manufacture; cyclone dust collectors; quick action air brakes under Westinghouse patents; pneumatic tires for automobiles; automobiles under the Selden patent; induction electric motors under Tesla patents; pressure filters; incandescent electric lamps; steam heating apparatus; typewriters; armored concrete construction; the calculagraph, etc.

He became a member of this Society in 1883 and was a member of the Council as Manager 1891 to 1894, and Vice-President 1894 to 1896, and 1899 to 1901.

He is a member of the American Institute of Electrical Engineers; La Société des Ingenieurs Civils de France; l'Association des Anciens Elèves de l'École Centrale des Arts et Manufactures; The Detroit Engineering Society; the Society for the Advancement of Science; the American Geographical Society; the Engineers' Club and the Ohio Society of New York.

CONVENTION NOTES

The members of the Local Committee of which Mr. H. F. Holloway was Chairman and the Ladies' Reception Committee, Mrs. Jesse M.

Smith, Chairman, did most effective work in providing for the welfare of the members and guests in attendance at the Convention. Both committees were divided into sub-committees to more effectually look after the varied interests for which it is necessary to provide in a large gathering of this kind.

A different reception committee was assigned to each morning, afternoon and evening during the convention, to promote sociability among the members and give any information desired. This plan added much to the enjoyment of the gathering in the foyer on the first floor, which really became the social place of the convention.

The Hotel Committee, D. H. Gildersleeve, Chairman, supplied those at the different hotels with the names of guests attending the convention and the hotels at which they were stopping.

The Council room in the Society's offices on the eleventh floor was used as headquarters for the ladies and afternoon tea was served. Members of the ladies committee were in attendance and the various excursions provided for the ladies were started from this point.

A new plan of registration was adopted this year which greatly favored registering. Each member was assigned a number in advance, the arrangement being an alphabetical one. This enabled the division of the list of members into three sections so that three lines of members could be registered simultaneously. Registration blanks were printed in advance with name and home address so that all the member had to do was to add his local hotel address. When a member registered he gave his name and received at once an envelope containing his badge and a filled out registration blank. In this way there were no delays incident to registration.

EXCURSIONS

A large number of excursions were arranged for the visitors through the untiring efforts of the Excursion Committee, Jas. V. V. Colwell, Chairman. Invitations were received to visit the following engineering works and plants, to each of which and their representatives, the thanks of the Society have been gratefully extended.

Pennsylvania Tunnels: Invitation by Alfred Noble, member of the Society; Manhattan Rubber Manufacturing Company, Passaic, N. J., by A. F. Townsend, President; Deep-Water Terminal, Pennsylvania R. R., by F. L. DuBosque, member of the Society; N. Y. Central & Hudson River R. R. Port Morris Power station, by E. B. Katte member of the Society; Goldschmidt-Thermit Co., by W. R. Hulbert,

member of the Society; High-Pressure Fire Service, by I. M. de Varona, Chief Engineer of the Department of Water Supply, Gas and Electricity; Waterside Stations, No. 1 and 2, New York Edison Co., by New York Edison Co.; Joseph Dixon Crucible Company, by Joseph Dixon Co., George E. Long, Treasurer, Jersey City, N. J.; The American Manufacturing Co., by The American Manufacturing Co., Anderson Gratz, President; The J. H. Williams Co., by J. H. Williams Co., Brooklyn, N. Y., J. H. Williams, President; Queensboro Bridge (Blackwell's Island Bridge), by the Commissioner, James W. Stevenson; Atha Tool Co., Newark, N. J., by Harry Atha, Treasurer; Swift & Company, by M. F. Mallon, Chief Engineer; Singer Tower and Power Plant, by Singer Manufacturing Co., E. P. Coleman, Secretary; Trenton Iron Co., Trenton, N. J., by Trenton Iron Co.; Brooklyn Navy Yard, by Admiral Caspar F. Goodrich, Commandant; John Thomson Press Co., Long Island City, by John Thomson, President; Metropolitan Tower and Power Plant, by Metropolitan Life Insurance Co.; Interborough Rapid Transit Co., 59th St. Power Plant, by Interborough Rapid Transit Co.; Manhattan Bridge, by Glendon Contracting Co., The Crocker-Wheeler Co., by Gans S. Drum, Vice-President.

Every possible courtesy was extended and in a number of cases, where a party was large, special transportation facilities were provided, luncheons served, and opportunity afforded for inspecting the apparatus and machinery. These parties were conducted by local members of the Society who generously volunteered their time and services. The Information Bureau conducted in the foyer of the Engineering Societies Building, Albert Spies, Chairman, was of material assistance in carrying out the excursions.

Excursions provided by the Ladies' Reception Committee, Mrs. Jesse M. Smith, Chairman, were also successfully carried out and several ladies served most efficiently as guides to points of interest about the city. Especially enjoyable were the automobile drives, afforded by Mrs. J. A. Kinkead.

DECEMBER MEETINGS OF THE COUNCIL

The regular meeting of the Council was held Tuesday, December 1, 1908, in the rooms of the Society.

There were present, Pres. M. L. Holman, in the Chair, Messrs. Breckenridge, Gates, Dodge, Fritz, Hutton, Hunt, Swasey, Stott, Taylor, Wellman, Wiley, and the Secretary.

The death of Mr. E. G. Eberhardt was reported.

In connection with the death of Mr. Herbert D. Hale, architect of the Engineering Societies Building, the Honorary Secretary was directed to draw up resolutions as expressing the sentiment of the Council.

The resignation of Louis Schaeffer was reported.

It was voted to grant to recognized book dealers a discount of 25 per cent from the price to non-members of the Society's publications.

The annual reports of Standing Committees to the Council were published in the December Journal.

The Committee on International Screw Threads reported a conference with the representative of the Society in Paris, Mr. Laurence V. Benet.

The Committee on the Land and Building Fund reported gifts of $1000 each from Mr. Worcester R. Warner and Mr. Ambrose Swasey.

The Secretary read a letter from President-Elect Taft, expressing his regret at being unable to attend the Annual meeting of the Society and participate in the discussion of the paper on "The Engineer and the People."

The Council directed that the invitation from the Government to participate in the National Conservation Commission Congress held in Washington, December 8, be accepted and the representatives notified.

Dr. W. F. M. Goss of the Government Advisory Board on Fuels and Structural Materials met with the Council. He was invited to be present at a later meeting together with the other members of the Committee.

Special Meeting of the Council

Continued from the regular meeting, December 1

A meeting of the Council was held on Friday, December 4, in the Council room of the Society.

There were present: Messrs. Holman, Bond, Breckenridge, Carpenter, Dodge, Hunt, Humphreys, Hutton, Gantt, Miller, Moultrop, Smith, Swasey, Taylor, Wellman, Whyte, Wiley, and the Secretary.

The meeting was called to order by Mr. Holman, the retiring President, who called Mr. Jesse M. Smith to the chair.

The Secretary thereupon retired, and Professor Breckenridge was made Secretary *pro tem.* The following resolutions were recorded:

Voted, that Mr. Calvin W. Rice be reëlected Secretary on the same terms and conditions as last year.

Voted that Prof. F. R. Hutton be reëlected Honorary Secretary on the same terms and conditions as last year.

The resignation of H. S. Richardson was accepted.

The rules governing Student Membership in the Society, prepared by a committee of the Council, were approved and ordered enforced.

Mr. Charles Wallace Hunt was named as the representative of this Society on the John Fritz Medal Committee upon the expiration of the term of office of Prof. John E. Sweet in January 1909.

Mr. Fred J. Miller was named as the representative of the Society on the Board of Trustees of the United Engineering Society.

The following resolutions were referred from the annual convention:

> That the President of the Society be and hereby is authorized to appoint a committee of seven members to memorialize Congress to authorize the purchase and erection of a large testing machine for the government and to state what size and quality of machine should in their judgment be purchased.
>
> That the Council be hereby requested to appoint a committee to investigate and report upon the adoption of standard systems of interchangeable involute gearing from 12-tooth pinions to racks.

A resolution was presented from the Aëro Club and from Mr. A. F. Zahm, Secretary of the International Aëronautical Conference at New York to the effect that The American Society of Mechanical Engineers request the President of the United States to call the attention of Congress to the advisability of providing the military departments of the Government with funds sufficient to establish aëronautic plants, proportionate to those of other nations.

The foregoing resolutions were laid on the table.

NATIONAL CONSERVATION CONGRESS

The Second Conservation Congress was held in Washington, D. C., December 8–10, to receive the report of the National Conservation Commission appointed by the President of the United States at the initial Conservation Congress of the Governors of all the states held in Washington last May.

There were present, besides the President and President-elect, the Governors of thirty-nine States, or their representatives; Senators and Representatives of various states; representatives of the largest commercial bodies and labor organizations and from railroads and the world of capital, as well as the national engineering societies. The delegates from this Society were Mr. Jesse M. Smith, President; and Prof. Geo. F. Swain, Messrs. L. D. Burlingame, Charles Whiting Baker and Calvin W. Rice, members of the Society's Conservation Committee. The Society was also represented by Mr. John R. Freeman, who, together with Professor Swain and Mr. Charles T. Main, was appointed by the Council of the Society upon an Advisory Board to the Committee on the Valuing of Water Powers, in response to a special invitation from the Government.

The meeting was opened by the Hon. Gifford Pinchot, with prayer by the Rev. Edward Everett Hale. President Roosevelt was the first speaker.

OPENING ADDRESS BY PRESIDENT ROOSEVELT

President Roosevelt in his address briefly reviewed the beginnings of the movement toward conservation, which resulted in the appointment of a National Conservation Commission whose inventory of the national resources of the country this congress has convened to receive. He advised the immediate beginning of the construction of waterways, for which plans have already been approved, and warned against the policy of procrastination, delay and partial action which have wasted vast expenditures in the past. He advocated the issue of bonds if the cost could not be paid immediately from the current revenues. He advised that the matter be approached from the view of national interest under the guidance of the wisest experts in engineering, in transportation, and in all the uses of our streams;

and advocated immediate measures for forest protection and the securing of the Appalachian and White Mountain national forests without delay.

The President spoke with great appreciation of the work of the "two great" national engineering societies, commending their hearty spirit of coöperation and promptness of attack. The participation of this Society in the enduring work of conservation was thus definitely recognized.

Prominent among the points emphasized by the President was that our country is the first to make an inventory of its natural resources. These inventories corroborate the estimates made at the first Conference that certain resources are about to be exhausted, and that therefore the creation of public sentiment and the consequent action toward conservation is most timely.

The President emphasized the effect which the conservation of forests has on the flow of streams. This theory is also supported by the Hon. Gifford Pinchot, Chief Forester of the United States, whose scientific investigation and application of his principles to practical conservation, wherever possible, have won for him the high regard of the country.

President Roosevelt again emphasizes this point in his message to Congress, supplying photographs and giving information in regard to parts of China and other countries from which the timber had been removed, leaving country once densely populated a barren waste supporting no life.

Governor Chamberlain of Oregon cited the Government's authority and jurisdiction over the undisposed portions of the public domain, and said that the power of Congress is there unquestionably supreme with respect to the soil, the mines, the forest, and the streams tributary to navigation.

President-elect Taft, who also addressed the Congress, said that the Constitution should be construed to give large powers to conservation because, to be effective, it must cover the whole country. It is necessary to nationalize the work of conservation, as no one State is financially equal to carrying out an adequate conservation policy. Mr. Taft agreed with President Roosevelt about the issuance of federal bonds for the funding of permanent national improvements.

REPORT OF THE CONSERVATION COMMISSION

The report of the Commission included recommendations for the enactment of such laws as may be necessary to extend coöperation,

and for the policy of the separate disposal of surface, timber and mineral rights remaining on public lands.

The Conference approved the disposal of mineral rights by lease only, and the disposal of timber rights only under conditions insuring proper cutting and logging.

Its policies in regard to waterways favor treating all portions of each waterway as inter-related, and recommend federal appropriation or the issue of bonds for the development of navigation, water supply and other state uses.

A resolution was adopted providing for the appointment of a joint Committee of State and National Commissions to prepare a plan for united action by all the organizations concerned.

REPORT ON FORESTS

The partial inventory of the forests of the United States was presented by Senator Reed Smoot of Utah, Chairman of the Section of Forests.

The report said in part:

Our forests now cover 550 000 000 acres, or about one-fourth of the United States. The original forests covered not less than 850 000 000.

We take yearly, including waste in logging and in manufacture, and not counting loss by fire, 23 000 000 000 cu. ft. of wood from our forests, which is 3½ times their yearly growth..

Under right management our forests will yield more than four times as much as now. We can reduce waste in the woods and in the mill at least one-third with present as well as future profit. We can perpetuate the naval stores industry. Preservative treatment will reduce by one-fifth the quantity of timber used in the water or in the ground. We can practically stop forest fires at a total yearly cost of one-fifth the value of the standing timber burned each year, not counting young growth. We shall suffer for timber to meet our needs until our forests have had time to grow again. But if we act vigorously and at once we shall escape permanent timber scarcity.

REPORT ON WATERWAYS

The report of the Section of Waters was in part as follows:

It has been roughly estimated that the inland waterways of the country could be improved in ten years at a cost of $50 000 000 annually in such manner as to promote inter-State commerce and at the same time greatly reduce the waste and extend the use of the waters.

There are in mainland United States 282 streams navigated for an aggregate of 26 115 miles, and as much more navigable by improvement; there are also forty-five canals, with a mileage of 2189.05, besides numerous abandoned canals. On lake and sound routes there is large traffic, but the navigation of rivers and

canals is too small for definite record. The cost of water carriage averaging about one-fourth that of rail carriage, and our railway freightage during 1906 reaching 217 000 000 000 ton miles, at an average rate of 0.77 cent, the shipping of one-fifth of our freight by water would have saved more than $250 000 000 to our producers and consumers.

The theoretical power of the streams is more than 230 000 000 horse power; the amount now in use is 5 250 000 horse power. The amount available at a cost comparable with that of steam installation is estimated at 37 000 000 horsepower, and the amount available at reasonable cost at 75 000 000 to 150 000 000 horse power. The 37 000 000 horse power exceeds our entire mechanical power now in use, and would operate every mill, drive every spindle, propel every train and boat and light every city, town and village in the country.

The broad plan already framed by statesmen and experts and approved by the Executive should be enacted into law; it provides for a system of waterway improvement extending to all of the uses of the waters and benefits to be derived from their control, including the clarification of the water and the abatement of floods for the benefit of navigation, the extension of irrigation, the development and application of power, the prevention of soil wash, the purification of streams for water supply and the drainage and utilization of the waters for swamp and overflow lands.

REPORT ON MINERALS

The report of the Minerals Section to the National Conservation Commission, of which Representative John Dalzell is Chairman, was presented. It is in part, as follows:

One-half of the natural gas now coming out of the earth, about 1 000 000 000 cu. ft. per day, or more than enough to light all the cities of the United States having more than 100 000 population, is wasted by being allowed to escape with the atmosphere. This entire waste can be prevented by adequate state legislation.

The waste in coal mining is equivalent to about one-half of the total product mined, or for the year 1907, 240 000 000 tons. The aggregate waste in mining coal, lead, zinc, copper, gold and silver for the past year is estimated to approximate $1 000 000 per day in value.

Even more serious than the waste of materials is the excessive loss of life in mining operations. During the past year in the coal mines alone more than 3000 men were killed and more than 7000 injured, and the number of men killed for the number employed in the United States, is from two to four times as great as in other coal-mining countries.

The known coal supply occupies an aggregate area of nearly 500 000 sq. miles, and is estimated to contain about 1 400 000 000 000 tons of accessible coal. This supply is estimated to last until the middle of the next century.

The known iron ore supply is estimated at 3 840 000 000 tons. At the present increasing rate of consumption, it will have been consumed by the middle of the present century.

The chief waste in our oil supplies is in their misuse for fuel purposes where coal, a more abundant fuel, might be appropriately used.

Definite estimates of the supply of copper, lead, zinc, and the precious metals cannot be made, but judging from the present supply, they will scarcely last beyond the present century.

The close of the Conference marked the first milestone in the definite effort to conserve for posterity the resources which until recently the unthinking have regarded as exhaustless. The part of the engineer in this important work is evident. To him it is given to execute. The true executive is the leader, and let the profession become alive to the possibilities which this new movement affords.

Mr. Carnegie in his address at the second annual banquet of the Engineers' Club impressed the need of definite action in the conservation movement by the Engineering Societies.

Annual Meeting of the Rivers and Harbors Congress

The plan for the issuance of $500 000 000 of government bonds for improvements of the rivers, harbors and canals of the country met with general approval at the Rivers and Harbors Congress held in Washington, December 9, 10 and 11.

Important personages in public, industrial and commercial life of the nation participated in the proceedings, among whom the following addressed the congress: Vice-President Fairbanks, Andrew Carnegie, James Bryce, the British Ambassador; ex-Mayor Seth Low, of New York; Representative Joseph E. Ransdell; Champ Clark of Missouri, minority leader of the House of Representatives; Governor George E. Chamberlain of Oregon, Governor J. Y. Sanders of Louisiana, Samuel Gompers, president of the American Federation of Labor; Judge George Hillyer, a member of the Georgia Railroad Commission, and Professor W. D. Lyman, of Whitman College, of Washington.

Vice-President Fairbanks, in extending to the Congress a cordial welcome to Washington, said that the time has arrived when we must give to the subject of obtaining adequate transportation facilities at a minimum cost intelligent and effective consideration.

Ambassador Bryce spoke of the waterways of England, and especially directed the attention of Americans to the splendid system of internal navigation of Germany.

Representative Ransdell, President of the Congress, advocated vigorous efforts to secure the prompt passage of a large river and harbor bill at this session of Congress, and the committal, on the

part of Congress, to a broad, liberal policy of waterway improvement and legislation providing for their equitable administration.

Andrew Carnegie made an address in which he warned the delegates against the considerat on of sectional projects, insisting that projects national in their scope are what is wanted.

Delegates to the Congress from New York State formed a New York State Waterways Association, to aid in the improvement of rivers and harbors of New York and of the country generally.

GENERAL NOTES

SUPPLEMENT TO THE JANUARY JOURNAL

With this number of The Journal is issued a supplement containing portraits of officers, officers and committees, charter, constitution and rules, periodicals in the engineering societies' library, membership lists, information upon the gas power section, new members elected, and related matter. Heretofore it has been customary to publish this material as a part of the January Journal at the beginning of the new year, following the election of new members, the appointment of officers and committees, etc. For greater convenience and in order to save time in publication, this material is, this year, issued as a supplement to The Journal for January. This enables us to publish a more complete list of new members, lists of committees and officers, a comprehensive list of periodicals in the Library, and the latest changes and additions made in the rules for the government of the Society.

THE ORGANIZATION OF STUDENT SECTIONS

The Society is pleased to announce the organization of two affiliated branches, one among the students at Stevens Institute, Hoboken, N. J., and the other at Sibley College, Cornell University, Ithaca, N. Y.

In order to provide for the affiliation of student organizations rules have been adopted in addition to those heretofore enacted for the guidance and organization of branches. These appear in the supplement to this number of The Journal and are most liberal in their provisions.

It is the desire of the Council to offer every inducement to young men about to enter the engineering profession to become associated with those actively engaged in successful engineering work and with engineers of prominence; and to supply them with the literature of the Society on the most liberal terms possible. The charge to members of student affiliated societies will be considerably less than the actual cost of the publications of the Society which are supplied them. Besides this opportunity of securing matter of so great an

educational value, there are the advantages mentioned of association with a body of established engineering reputation.

The distinction of being the first student branch of the Society belongs to the Stevens Engineering Society of Stevens Institute, Hoboken, N. J. A new Constitution has been drafted by them to include the larger scope of the Engineering Society and at a meeting on November 21 the requirements for student branches were taken up for discussion and accepted. Dr. Alexander C. Humphreys was nominated as Honorary President, in accordance with the provisions. Under the new arrangement this society retains its own identity and is still controlled by student officers under the direction of its Honorary President.

At a meeting at Sibley College, Cornell University, on December 9, the first steps were taken toward the organization of a Cornell Student Branch of the Society. Prof. R. C. Carpenter was chosen Honorary President, and an executive committee was appointed consisting of Profs. D. S. Kimball, H. Diederichs, and W. N. Barnard. Prof. C. F. Hushfeld was elected corresponding secretary. The meeting was attended by the following members of the Society: W. N. Barnard, R. C. Carpenter, G. D. Conlee, H. Diederichs, H. D. Hess, H. Wade Hibbard, C. F. Hirshfeld, D. S. Kimball and R. L. Shipman. As soon as possible the organization of the student membership of the branch will be completed and by-laws are now being drawn up by the Executive Committee.

LOST ARTICLES

Any one losing articles at the Reception Thursday evening of the Annual Convention should communicate with the Secretary. A few small articles were found which we are anxious to return to the owners.

TABLET IN HONOR OF ANDRE-MARIE AMPERE

The Society was invited to be present at the unveiling of a bronze and tile memorial tablet in honor of the French scientist Andre-Marie Ampere which was set up in the Lackawanna railroad station at Ampere, N. J., by Dr. Schuyler Skaats Wheeler, Past President A. I. E. E. The memorial was unveiled December 3 by his Excellency M. Jusserand, the French Ambassador.

Andre-Marie Ampere, who founded the science of electro-dynamics, and whose name is used throughout the world to designate the unit of electric current, was born at Lyons 1775 and died at Marseilles 1836.

FOREST FESTIVAL OF THE BILTMORE ESTATE

Reforestation, which is second in importance only to the preservation of forests, has been brought to a successful stage of development on the Biltmore Estate at Biltmore, N. C.

A "Forest Festival" was held Nov. 26–28 when visitors were conducted over the estate, and the growth of the forests planted between 1889 and the present date reviewed. The Biltmore Estate, under the direction of Dr. C. A. Schenck, Chief Forester, and Charles A. Waddell, Engineer, Mem. Am. Soc. M. E., has taken the lead of forestry in America. Dr. Schenck stated to the guests that forestry on the estate had been profitable.

Mr. Charles E. Waddell was appointed Honorary Vice-President for this occasion to represent the Society. At the dinner on November 27, Mr. Waddell, as the engineer of the Biltmore Estate, extended a welcome to the visitors, and as representative of the Society extended the Society's cordial and fraternal greetings. He spoke of the Society's interest in conservation, and touched upon its participation in the conservation movement and mentioned that the Society has been requested by the Government to appoint a special advisory board to the National Conservation Commission.

INVITATION FROM THE ENGINEERS' CLUB OF TORONTO

The Engineers' Club of Toronto, Canada, has extended to the members of the Society, when visiting in Toronto, the privileges of the club rooms. The Society reciprocates by offering the courtesies and conveniences of the Society rooms to visiting members of the Toronto Club.

INSTITUTE OF MINING ENGINEERS

An invitation has been extended to the members of the Society by the American Institute of Mining Engineers, to attend the annual meeting of the Institute at New Haven, Conn., which begins on Tuesday, February 23. There will be an important paper by Mr. Henry G. Granger on The Construction of a Sea Level Panama Canal. The Conservation of Natural Resources is to be discussed and the subject of Professional Education, in connection with an inspection of the Hammond Laboratories of the Sheffield Scientific School. The secretary, Mr. R. W. Raymond, will attempt to arrange hotel accommodations for members of the Society who attend.

OTHER SOCIETIES

THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers at their Annual Meeting, January 20, 1909, will take up the discussion of the metric system. The report of a special committee of that Society, which will be presented, strongly favors the general adoption of the metric system, not merely for scientists and engineers.

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

The American Society of Refrigerating Engineers held their fourth annual meeting November 30 and December 1 at the Engineering Societies Building, New York. The following officers were elected: President, Louis Block, New York; Vice-President, Homer McDaniel, Cleveland, O.; Treasurer, Walter C. Reid, New York; Directors, Madison Cooper, New York; N. H. Hiller, Carbondale, Pa.; W. H. Manus, Waynesboro, Pa.

A paper on "The Relative Bacteriological Contents of Can, Plate and Natural Ice under Various Conditions "was presented by Mr. J. C. Sparks; Mr. C. C. Palmer contributed a paper on "Ethyl Chlorid Refrigeration;" "The Construction and Actual Results Obtained from an Ice Making Plant of Moderate Size" was the title of a paper presented by Mr. Charles Dickerman.

One session was devoted to waterproofing and concrete tanks. Mr. W. M. Torrance presented "Reinforced-Concrete Freezing Tanks" and "Waterproofing in Refrigerating Work" was contributed by Mr. Edward W. De Knight. Other papers were: "Standard Method of Testing Refrigerating Machines" by Prof. D. S. Jacobus; "Performance of Ammonia Compression Machines" by Prof. C. E. Lucke; "Does Ammonia Disintegrate in Absorption Plants?" by Mr. Herman Dannenbaum; "Refrigeration Applied to Air Supply for Blast Furnaces" by Mr. Bruce Walter; "Investigations in the Handling of Perishable Products" by Mr. H. G. Powell.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The Annual Meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York, November 19 and 20.

The following Vice-Presidents were elected: Mr. F. L. Fernald, Naval Constructor, U. S. N., Eliot, Me.; Mr. Stevenson Taylor, Quintard Iron Works, New York; Mr. W. M. McFarland, Westinghouse Electric and Manufacturing Co., Pittsburg. Ten members of the Council of the Society were also elected. The terms of office of the other officers had not expired.

Mr. Charles H. Cramp presented a paper upon the "War Eagle," the name of a famous fast sailing vessel of the "Baltimore clipper" type. "The Oldest Iron Ship in the World" was the title of a paper contributed by Mr. Henry Penton of Cleveland, O. A paper on "The British International Trophy Race of 1908" was presented by Mr. W. P. Stevens of Bayonne, N. J. Other papers were: "Shipbuilding on the Great Lakes" by Mr. Robert Curr, Naval Architect of Cleveland, O.; "The Steamer 'Commonwealth' " by Mr. W. T. Berry, and Mr. J. H. Gardner; "Centrifugal Fire Boats" by Mr. C. C. West; "Sea-Going Suction Dredges" by Mr. T. M. Cornbrooks; "Recent Inventions Applied to Modern Steamships" by Mr. W. C. Wallace.

In addition to these historical and descriptive papers, the following papers on design were contributed:

"The Influence of Midship-Section Shape Upon the Resistance of Ships" by Mr. D. W. Taylor; "Experiments on Longitudinal Distribution of Displacement and its Effect on Resistance" by Prof. H. C. Sadler; "Further Analysis of Propeller Experiments" by Mr. C. H. Crane; "The Influence of Free Water Ballast Upon Ships and Floating Docks" by Mr. T. G. Roberts.

There were also papers on trials and operations as follows: "Practical Methods of Conducting Trials of Vessels" by Col. E. A. Stevens; "Service Test of the Steamship 'Harvard'" by Prof. C. H. Peabody, Prof. W. S. Lelande, and Mr. H. A. Everett; "Trials of the U. S. Scout Cruiser 'Chester' " by Mr. C. P. Wetherbee: "Some Remarks on the Steam Turbine" by Mr. J. W. Powell; "The Transportation of Submarines" by Mr. W. J. Baxter; "Deviation of the Compass aboard Steel Ships—its Avoidance and Correction" by Lieut.-Commander L. H. Chandler, U. S. N.

The social event of this convention was the banquet held at Delmonico's, on the evening of the second day.

ANNUAL MEETING OF THE SOCIETY OF AUTOMOBILE ENGINEERS

Members of The American Society of Mechanical Engineers are invited to attend the sessions of the fourth annual meeting of the Society of Automobile Engineers which opens on Tuesday, January 5, at the building of the Automobile Club of America, 54th Street, New York. The morning of the first day will be devoted to tests of different cars on the club dynamometer under the supervision of Henry Souther. Several papers upon subjects related to the design of automobile mechanism are announced. The technical sessions will be held in The Engineering Societies Building on 39th Street.

MEETING OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

On the evening of December 11, the Electrical Engineers held a largely attended meeting in the Engineering Societies Building. W. S. Murray, Electrical Engineer of the New York, New Haven and Hartford Railroad Company, presented a paper upon The Log of the New Haven Electrification.

The paper drew out a discussion that was prolonged until after midnight. As usual at Institute meetings, where the subject has to do with the electrification of trunk line railways, the discussors were sharply divided into direct current and alternating current groups. In the resulting contention there was a tendency to overlook the broad engineering features of the paper and for some time the discussion narrowed down to a comparison of the operating conditions on the New York Central and Hudson River Railroad and those on the New Haven Railroad. This was marked in the discussion of the types of locomotives used on the two roads,—the greater draw bar pull per pound of motor weight afforded by the direct current motor *versus* the continuous capacity rating of the single-phase alternating current motor. Later in the evening, however, the drift of the discussion changed and several prominent engineers brought up the broad question of the lowest cost, including fixed charges, between the coal pile and the fare.

BANQUET OF THE ENGINEERS' CLUB

The second Annual Banquet of the Engineers' Club of New York was held at the club house on Saturday evening, December 12. Andrew Carnegie was the guest of honor and other speakers were P. T. Dodge, President of the Club, John Hays Hammond, Presi-

dent of the American Institute of Mining Engineers, Prof. Brander Matthews, Columbia University, and Col. George Harvey, President, Harper and Brothers.

Mr. Carnegie took the opportunity to urge members of the engineering profession to take an active part in the movement for the conservation of our natural resources. He stated that there was no more patriotic duty which the engineers as a body could perform. Mr. Carnegie closed with the statement of his satisfaction in the development of the use of the building of the Engineering Societies and the accompaniment of the social side in the Engineers' Club. The two go hand in hand.

Dr. Hammond spoke with reference to the engineer in politics and predicted that the engineer would more and more take his place in the affairs of the nation by virtue of his training, his directness of method and his rugged honesty; to the same degree which our lamented John Hay had emphasized the success of honesty in diplomacy so the engineer would make a success in politics.

Professor Matthews spoke interestingly on the subject of Simplified Spelling, and President Harvey gave a scholarly address on the relation of the engineer to politics and an encouragement to him to participate in all public affairs.

The souvenir of the occasion was a beautifully designed menu by Tiffany giving photogravures of Mr. Carnegie and of familiar scenes in the rooms of the Engineers' Club. Considerably over 200 were present, among them being the President, Secretary and other members of the Society.

NECROLOGY

DEATH OF R. H. SOULE

It is with great regret that we announce the death of Mr. Richard H. Soule, a charter member of the Society. A full and complete memorial notice will be published in the February issue.

ARVY ELROY WELLBAUM

Mr. Arvy Elroy Wellbaum was born February 12, 1881, at Brookville, Ohio, where he attended the high school. He studied at the Ohio Northern University, Ada, Ohio, for one year, and received the degree of M.E. in 1902 from Ohio State University. During the summer vacations he was in the employ of the C. & G. Cooper Co., Mt. Vernon, O., and Platt Iron Works Co., Dayton, Ohio.

In 1902 he became draftsman for the Morgan Engineering Co., Alliance, O. He became connected with the Foos Manufacturing Co., Springfield, O., in 1903, as designing draftsman, and in 1905 he accepted a similar position with the Foos Gas Engine Co., Springfield, O. For three years he was instructor of mechanical drawing and machine design in the Young Men's Christian Association of Springfield, O. Up to the time of his death, August 31, 1908, he was associated with The Hydraulic Press Co., Mt. Gilead, Ohio, having had charge of the engineering department.

ELMER G. EBERHARDT

Elmer G. Eberhardt of Newark, N. J., an Associate Member of the Society, died at his home on November 21, 1908. He was born in Newark, April 26, 1881, and was graduated from the Newark High School in 1896 He received his technical education in Stevens Institute and Cornell University, receiving the degree of M.E. at the latter institution in 1904.

He learned the machine trade with his father, Henry E. Eberhardt, of the firm of Gould and Eberhardt, at Newark, and upon graduation from Cornell University, he formed, with his father and brothers, the firm of Eberhardt Brothers Machine Co., now the Newark Gear Cutting Machine Co. Mr. Eberhardt was Vice-president of the company, and

was engaged in the design of automatic gear-cutting machines, in which field he invented a number of improvements as well as investigated along original lines. He was a frequent contributor to the technical columns of the mechanical papers. He designed the power plant and equipment of the factory with which he was connected.

Mr. Eberhardt was elected president of the Cornell Society of Electrical Engineers and Vice-president of the Cornell Mechanical Society, as well as receiving the honorary key of Sigma Xi for high scholarship in the scientific branches. He was an Associate Member of the American Institute of Electrical Engineers, and a member of the University Club of Newark and the Cornell Association of Northern New Jersey.

At the time immediately preceding his death, Mr. Eberhardt was engaged, aside from his business connections, in consulting engineering work, in matters relative to gears and gear cutting.

EDWARD L. JENNINGS

Edward Lobdell Jennings, whose death occurred on November 6, 1908, was born in North Wayne, Me., April 14, 1850. He received his education in the public schools of his native town and at the Maine Wesleyan Academy. He was apprenticed to the North Wayne Tool Company, and in 1872 he went to Boston and entered the employ of W. A. Wood & Co. and was their manager for several years. He resigned his position with this company and removed to Waterbury to take the position of purchasing agent for the American Brass Co., held for the eight years preceding his death.

Mr. Jennings was a member of the Waterbury Club, a Commandery Mason and a member of the First Church (Congregational), Waterbury, Conn.

EDWIN H. JONES

Edwin Horn Jones was born in Wilkes-Barre, Pa., April 15, 1844, and died December 2, 1908. He was educated at the Old Dow Academy on South Franklin Street, and at an early age he entered the employ of his father, Richard Jones, who then conducted the Jones Foundry, the foundation of the present extensive Vulcan Iron Works. He learned the iron business thoroughly, advanced to Superintendent of the works, and at the time of his father's death in 1873 he became general manager of the company and later its president, a position he held until the time of his death.

As President of the Vulcan Iron Works he consolidated the Wyoming Valley Manufacturing Co. and the Pittston Iron Works with the

original plant and later purchased the Tamaqua shops, all of which he consolidated as the Vulcan Iron Works.

Nearly twelve years ago he was made President and General Manager of the Sheldon Axle Works. In 1881 he became Director of the Second National Bank, and later its Vice-President. He was interested as stockholder and director in a number of other industries and was an active member of the Wilkes-Barre Board of Trade and one of its trustees. He was a member of the Westmoreland Club and the Wyoming Valley Country Club, the Arts Club of Philadelphia, and the Sons of the Revolution. He was a member of the Central M. E. Church.

PERSONALS

Mr. W. L. Bronaugh has just organized the Iroquois Engineering Co., which will represent the Fitzgibbons Boiler Co.,with offices at 1211 Fisher Bldg., Chicago, Ill., Mr. Bronaugh has recently been in the employ of the B. F. Sturtevant Co., as manager of the Chicago house.

Mr. George A. Orrok, Mechanical Engineer of the New York Edison Co., delivered a lecture on Central Station Design at a me ting of the Modern Science Club, Brooklyn, Tuesday evening, October 27.

Mr. H. de B. Parsons was appointed by the Governor a delegate from the State of New York to the conference of the Atlantic Deep Waterways Association, held in Baltimore, Md., on November 17–18, 1908.

Mr. James A. Pratt, who for the past two years has held a position as Instructor in Machine Work at Pratt Institute, Brooklyn, N. Y., has been appointed to a similar position at Williamson Free School of Trades, Delaware County, Pa.

Mr. Ellis Soper has resigned the positions of Vice-Presidents of the Hunt Engineering Co., Iola, Kansas, and Superintendent of the Dixie Portland Cement Co., S. Pittsburg, Tenn., to become President of The Soper Company with headquarters at 1110–11 Ford Building, Detroit, Mich. This company has been organized for the purpose of dealing in all standard cement machinery and doing general cement engineering work.

Messrs. Fred H. Colvin and Frank A. Stanley, Associate Editors of the American Machinist, are co-authors of the American Machinists' Handbook and Dictionary of Shop Terms.

Mr. Edmund Kent has resigned his position with the Boston and Montana Consolidated Copper and Silver Mining Co., Butte, Montana.

Professor William Kent, who has until recently been Dean of the L. C. Smith College of Applied Science, Syracuse University, Syracuse, N. Y., is to become General Manager of the Sandusky Foundry and Machine Co., Sandusky, O.

Mr. Oscar E. Perrigo is President of the Modern Systems Correspondence School Co., which has recently been organized with offices at 6 Beacon St., Boston, Mass., and 132 Nassau St., New York. The purpose of the Company will be to conduct a Correspondence School of instruction in Modern Cost Systems, Factory and Commercial Office Systems, Shop Methods and Systems, etc. Mr. Norman W. Henley is Secretary and Treasurer of this organization.

THE CONSERVATION IDEA AS APPLIED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PRESIDENTIAL ADDRESS 1908

By President M. L. Holman, St. Louis, Mo.

The rate at which the natural resources of the United States are being consumed caused the President to call a conference of the Governors of the States in 1908 to consider the questions of the conservation and use of the great fundamental sources of wealth of the Nation. That the question is considered a vital one, is shown by the fact that the conference marks the first time in the history of our country when the Governors of the States have assembled at the White House to consult with the Chief Executive of the Nation.

2 Invitations to participate in the Conference were issued to some 71 "National Organizations concerned in the development and use of" natural resources, and "to the Senators and Representatives in Congress; the Supreme Court; the Cabinet; and the Inland Waterways Commission." With the Governors were three men from each State chosen as advisers.

3 The Conference assembled in the East Room of the White House, Wednesday, May 13, 1908, and the morning session was taken up by the address of the President, on Conservation as a National Duty. During the sessions of Wednesday and Thursday the following papers were presented:

- The Conservation of Ores and Related Minerals, by Andrew Carnegie.
- The Waste of Our Fuel Resources, by Dr. White.
- The Natural Wealth of the Land and its Conservation, by James J. Hill.
- Soil Wastage, by Prof. T. C. Chamberlain.
- Forest Conservation, by R. A. Long.
- Resources Related to Irrigation, by George C. Pardee.
- Grazing and Stock Raising, by H. A. Jastro.

Presented at the New York Meeting (December 1908) of The American Society of Mechanical Engineers. All papers are subject to revision.

4 A limited general discussion was had on each of these papers. The immediate result of the Conference could be an expression of opinion only, in the form of resolutions. Pursuant to a motion the president appointed a Committee on Resolutions, consisting of the Governors of South Carolina, Utah, Wisconsin, Louisiana and New Jersey.

5 The four national Engineering Societies were represented by their presidents, who formed a part of the audience and who jointly presented resolutions which went, with others, to the Committee on Resolutions. The object sought by these representatives was a broad treatment of the subject on non-political lines, and an avoidance of any indication of departmental jealousy. During the discussion it became apparent that some effort would be required to keep the Conference from political bias. On Friday morning the Committee on Resolutions being ready to report, the reading of the papers set for Friday was suspended and the resolutions prepared were introduced. The President presided and under his skilful parliamentary guidance the resolutions were adopted without a dissenting vote.

6 The report of the Committee has not been given the publicity which it deserves and I therefore give it in full, as published in the Cincinnati Inquirer of May 16, 1908:

We the Governors of the States and territories of the United States of America in conference assembled, do hereby declare the conviction that the great prosperity of our country rests upon the abundant resources of the land chosen by our forefathers for their homes and where they laid the foundation of this great nation.

We look upon these resources as a heritage to be made use of in establishing and promoting the comfort, prosperity and happiness of the American people, but not to be wasted, deteriorated or needlessly destroyed.

We agree that our country's future is involved in this; that the great natural resources supply the material basis upon which our civilization must continue to depend, and upon which the perpetuity of the nation rests.

We agree, in the light of facts brought to our knowledge and from the information received from sources which we cannot doubt, that this material basis is threatened with exhaustion. Even as each succeeding generation from the birth of the nation has performed its part in promoting the progress and development of the republic, so do we in this generation recognize it as a high duty to perform our part, and this duty in large degree is in the adoption of measures for the conservation of the natural wealth of the country.

We declare our firm conviction that this conservation of our natural resources is a subject of transcendant importance, which should engage unremittingly the attention of the nation, the State and the people in earnest coöperation. These natural resources include the land on which we live and which yields our food; the living waters which fertilize the soil, supply power and form great avenues of commerce; the forests which yield the materials for our homes, prevent erosion

of the soil, and conserve the navigation and other uses of our streams; and the minerals, which form the basis of our industrial life, and supply us with heat, light and power.

We agree that the land should be so used that erosion and soil wash should cease; that there should be reclamation of arid and semi-arid regions by means of irrigation, and of swamp and overflowed regions by means of drainage; that the waters should be so conserved and used as to promote navigation, to enable the arid regions to be reclaimed by irrigation and to develop power in the interests of the people; that the forests, which regulate our rivers, support our industries and promote the fertility and productiveness of the soil, should be preserved and perpetuated; that the minerals found so abundantly beneath the surface should be so used as to prolong their utility; that the beauty, healthfulness and habitability of our country should be preserved and increased; that the source of national wealth exists for the benefit of all the people, and that the monopoly thereof should not be tolerated.

We commend the wisdom of the President in sounding the note of warning as to the waste and exhaustion of the national resources of the country, and signify our appreciation of his action in calling this Conference to consider the same, and to seek the remedies therefor through coöperation of the nation and the states.

We agree that this coöperation should find expression in suitable action by the Congress within the limits of and co-extensive with the national jurisdiction of the subject and complementary thereto by the Legislatures of the several States within the limits co-extensive with their jurisdiction.

We declare in convention that in the use of the national resources our independent states are interdependent and bound together by ties of mutual benefits responsibilities and duties.

We agree in the wisdom of future conferences between the President, members of Congress and the Governors of the States, regarding the conservation of our natural resources with the view of continued operation and action on the line suggested, and to this end we advise that from time to time, as in his judgment may seem wise, the President call the Governors of the States, members of Congress and others into conference.

We agree that further action is advisable to ascertain the present condition of our national resources and to promote the conservation of the same. And to that end we recommend an appointment by each State of a commission on the conservation of natural resources, to coöperate with each other and with any similar committee on behalf of the Federal Government.

We urge that continuation and extension of forest policies be adopted to secure the husbanding and renewal of our diminishing timber supply, prevention of soil erosion and the protection of head waters and the maintenance of the purity and navigability of our streams. We recognize that the private ownership of forest land entails responsibilities in the interests of all the people, and we favor the enactment of laws looking to the protection and replacement of privately owned forests.

We recognize in our waters a most valuable asset of the people of the United States, and we recommend the enactment of laws looking to their conservation, to the end that navigable and source streams may be brought under complete control and fully utilized for every purpose. We especially urge on the Federal Congress the immediate adoption of a wise, active and thorough waterway policy

providing for the prompt improvement of our streams and conservation of their water-sheds required for the uses of commerce and the protection of the interests of our people.

We recommend the enactment of laws looking to the prevention of waste in the mining and extraction of coal, oil, gas and other minerals with a view to their wise conservation for the use of the people and to the protection of human life in the mines.

Let us conserve the foundations of our prosperity.

FUNDAMENTAL CONSTANTS

7 As it is the peculiar function of the engineer to assist in making some of the resources of nature available for the use and convenience of man, we may well spend our time this evening considering a few of the phases of the problem. The President particularly desired the coöperation in the movement of the engineers of the United States and subsequently ascribed to the action of the Engineering Societies the credit of inaugurating the conservation campaign on non-political lines.

8 As it was the rapidly increasing rate of consumption of our natural resources that induced the President to make a new departure along the line of "States' Rights" and to call on the Governors for a conference, let us first examine into the forces at work consuming our national inheritance and turn our attention to ourselves, as the primary cause or force that is so rapidly dissipating the natural resources of the nation and emptying the store house of nature. For purposes of the present discussion we will confine ourselves to the territory of the United States. Table 1, compiled from the census returns, gives in a condensed form the fundamental constants and the independent variables of our problem, that is, our lands and inland waters and our population, as they stood in 1900.

TABLE 1 LAND AND WATER, AND POPULATION OF THE STATES OF THE UNITED STATES

State or Territory	SQUARE MILES			Population	Density
	Gross Area	Water	Land		
Alabama	52,250	710	51,540	1,828,697	35.5
Arizona	113,020	100	112,920	122,931	1.1
Arkansas	53,850	805	53,045	1,311,564	24.7
California	158,360	2380	155,980	1,485,053	9.5
Colorado	103,925	280	103,645	539,700	5.2
Connecticut	4,990	145	4,845	980,420	187.5
Delaware	2,050	90	1,960	184,735	94.3

TABLE 1—Continued

State or Territory	Square Miles: Gross Area	Square Miles: Water	Square Miles: Land	Population	Density
District of Columbia	70	10	60	278,718	4645.3N.B.
Florida	58,680	4440	54,240	528,542	9.7
Georgia	59,475	495	58,980	2,216,331	37.6
Idaho	84,800	510	84,290	161,772	1.9
Illinois	56,650	650	56,000	4,821,550	86.1
Indiana	36,350	440	35,910	2,516,462	70.1
Indian Territory	31,400	400	31,000	392,060	12.6
Iowa	56,025	550	55,475	2,231,853	40.2
Kansas	82,080	380	81,700	1,470,495	18.0
Kentucky	40,400	400	40,000	2,147,174	53.7
Louisiana	48,720	3300	45,420	1,381,625	30.4
Maine	33,040	3145	29,895	694,466	23.2
Maryland	12,210	2350	9,860	1,188,044	120.5
Massachusetts	8,315	275	9,040	2,805,346	348.9
Michigan	58,915	1485	57,430	2,420,982	42.2
Minnesota	83,365	4160	79,205	1,751,394	22.1
Mississippi	46,810	470	46,340	1,551,270	35.5
Missouri	69,415	6[illegible]0	6[illegible]735	3,106,665	45.2
Montana	146,0[illegible]0	770	145,310	243,329	1.7
Nebraska	77,510	670	76,840	1,066,300	13.9
Nevada	110,700	960	109,740	42,335	0.4
New Hampshire	9,305	300	9,005	411,588	45
New Jersey	7,815	290	7,525	1,883,669	250.3
New Mexico	122,5[illegible]0	120	122,460	195,310	1.6
New York	49,170	1550	47,620	7,268,894	152.6
North Carolina	52,250	3670	48,580	1,893,810	39.0
North Dakota	70,7[illegible]5	600	70,195	319,146	4.5
Ohio	41,0[illegible]0	300	40,760	4,157,545	102.0
Oklahoma	39,030	200	38,830	398,331	10.3
Oregon	96,030	1470	94,560	413,536	4.4
Pennsylvania	45,215	230	44,985	6,302,115	140.1
Rhode Island	1,250	197	1,053	428,556	407.0
South Carolina	30,570	400	30,170	1,340,316	44.4
South Dakota	77,650	800	76,850	401,570	5.2
Tennessee	42,050	300	41,750	2,020,616	48.4
Texas	265,780	3490	262,290	3,408,710	11.6
Utah	84,970	2780	82,190	276,749	3.4
Vermont	9,565	430	9,135	343,641	37.6
Virginia	42,450	2325	40,125	1,854,184	46.2
Washington	69,180	2300	66,880	518,103	7.7
West Virginia	24,780	135	24,645	958,800	38.9
Wisconsin	56,040	1590	54,450	2,069,042	38.0
Wyoming	97,890	315	97,575	95,531	0.9
Totals and Averages			2,971,038	76,357,575	25.7

TABLE 2 PUBLIC LANDS, JULY 1, 1908

FROM REPORT OF THE GENERAL LAND OFFICE OF THE UNITED STATES

States	Acres	States	Acres
Alabama	129,713	Montana	46,532,440
Alaska	368,021,509	Nebraska	3,074,658
Arizona	42,769,202	Nevada	61,177,050
Arkansas	1,060,185	New Mexico	44,777,905
California	29,872,493	North Dakota	2,322,150
Colorado	23,696,697	Oklahoma	86,339
Florida	414,942	Oregon	16,957,913
Idaho	26,785,002	South Dakota	6,561,295
Kansas	171,446	Utah	36,578,998
Louisiana	116,249	Washington	4,635,001
Michigan	135,551	Wyoming	37,145,302
Minnesota	1,788,705		
Mississippi	42,791	Total	754,895,296
Missouri	27,480		

9 While dealing with statistics of population, it may not be amiss to call attention to the fact that we are not always governed by the will of the majority. Table 3, from the census returns, shows quite the opposite; in fact it is about an even chance that a successful presidential candidate represents the majority of the voting population:

TABLE 3 PRESIDENTIAL VOTE

Year	Total popular vote	WINNING CANDIDATE		
		Popular vote	Per cent of total	Per cent of population
1828	1,156,328	647,231	55.97	....
1832	1,250,799	687,502	54.96	....
1836	1,498,205	761,549	50.83	....
1840	2,410,778	1,275,017	52.89	14.1
1844	2,698,611	1,337,243	49.55	....
1848	2,861,908	1,360,101	47.36	....
1852	3,138,301	1,601,474	50.90	....
1856	4,053,967	1,838,169	45.34	....
1860	4,676,853	1,866,352	39.91	15.2
1864	4,024,792	2,216,067	55.06	....
1868	5,724,684	3,115,071	52.67	....
1872	6,466,165	3,597,070	55.63	....
1876	8,412,733	4,033,950	47.95	....
1880	9,209,588	4,449,053	48.26	18.3
1884	10,044,985	4,911,017	48.48	....
1888	11,372,299	5,440,216	47.83	....
1982	12,059,351	5,556,918	45.73	....
1896	13,923,202	7,104,779	50.49	....
1900	13,967,974	7,217,810	51.66	18.4
1904	13,513,995	7,620,670	57.13	....

10 It will be noted that President Lincoln was elected by 40 per cent of the popular vote and that President Roosevelt received the greatest per cent of the popular vote since 1828. As new parties are developed the chances of government by the minority become greater, and with a sufficient number of political parties in the field, revolutions will be the order of the day.

HEALTH

11 Of our many resources, the most important one is the health of the people. The safeguarding of the general health and the prevention of preventable diseases form a large field for the practical operation of the conservation idea and will require the best efforts of the State and the Nation, the sanitary engineer and the health officer. The experience of the last decade has shown that prompt action by competent specialists backed by the power of the Government will conserve to the State, the community and the citizen, an earning power and working capacity that would otherwise be lost or diminished. The preventive work, particularly in zymotic diseases, must fall to the sanitarian and not to the physician, unless we adopt the Chinese practice of paying our doctors to keep us in good health and stop the honorarium when we fall sick.

12 A sharp distinction must be drawn between protecting people from unnecessary sickness and restoring the sick to health. The medical profession is an ancient and honorable one. It has accomplished a vast amount of good and has furnished a multitude of noble examples of devotion to duty. It is not my purpose to criticise the profession, but to draw attention to the fact that we need and must have comprehensive organizations, State, National, and municipal, which have for their field of work the protection of health. The training of the physician, and particularly his experience, are directed along lines that develop the specialist, but as a general rule executive training and experience are lacking. Our municipal records furnish much evidence to the fact that successful physicians, called from private practice, are totally devoid of executive ability. There have been exceptions, but they only emphasize the rule. Some States and cities now have Boards of Health, but for the most part they are composed of physicians and the work handled is the cure and not the prevention of disease. Less than one-half of the States record all deaths and require burial permits, and but few States keep accurate accounts of epidemics and contagious diseases.

13 Our school children are not properly protected from zymotic diseases. Some work in this direction, however, is now being undertaken by New York City. Our business interests suffer large losses from epidemics and generally work to prevent quarantine and other evidences of the true state of affairs from becoming public. Too much emphasis cannot be put on this part of the conservation problem. The public health is our most valuable resource and its protection and conservation is of the utmost importance.

14 One of the first problems in the field of sanitation is the protection of our rivers, lakes and other sources of domestic water supply from pollution. At present most, if not all, of our inland cities and towns discharge raw sewage into the natural water courses and lakes. One notable city for years discharged its sewage into the margin of a lake and took its water supply from the same place. Typhoid fever, resulting from this arrangement of sewage disposal and water supply, was prevalent and widespread. The general Government, through a National Sanitary Commission should have intervened for the protection of the citizens of other states and the residents of the city. This condition, in a slightly modified degree, still exists, and the necessity for a sanitary overhauling is evident to any unbiased student. Of late a portion of the sewage has been diverted out of the natural water-shed of the lake, but the conditions are far from safe, and a movement is now on foot to divert the remaining sewage ultimately, under the guise of an improved water-way. In this particular instance the sewage should be purified and discharged at the cost of the municipality producing it. An effort to force this treatment of the case resulted in a "Scotch verdict" and the present conditions may be expected to continue until there is a general movement looking to the protection of our water courses from pollution, or until each community develops a distinct bacillus that can be positively identified. In the matter of protecting our rivers and water courses from pollution, we are far behind the times and should begin our conservation era with laws prohibiting all parties, private and public, from burdening the country with filth that should be handled by the parties producing it, and at said parties' own proper cost and expense.

15 In addition to the protection of our sources of water supply the purification of the water furnished to cities must be given attention. It is an open question to what extent the State should exercise its power in this direction, but there is no question as to the results which an impure water supply entails, and the responsibility, morally if not legally, of the municipality which furnishes polluted water. It is my

opinion that the State should require the municipality, which it empowers to levy taxes, to discharge its full duty to its citizens. When a private water company supplies water it is under obligation to furnish a safe drinking water, just as fully as it would be to furnish adequate fire protection.

16 We have not the time this evening to enter into a detailed discussion of any of the problems involved in water purification, but an examination of the results obtained in the city of Washington for the years 1896 to 1897 is ample evidence to convince anyone of what may be accomplished. Numerous other cases might be cited showing good returns in life and health. The evidence is convincing, and the conclusion certain that the residents of our country suffer much bodily harm and unnecessary loss of life from drinking diluted sewage. Life insurance companies make us pay high rates for our negligence and pile up vast sums of money which is often manipulated to increase our burdens further. The reports of the insurance commissioner of the State of Connecticut show for 19 of the large insurance companies total assets amounting to the enormous sum of $2,718,631,737 and liabilities of $2,591,534,168.

FOOD

17 The next phase of the problem relates to the individual, and is not primarily within the field of the engineer, nevertheless the mechanical engineer has been at the bottom of a share of the trouble, by way of the cold-storage warehouse. No fault is to be found with the work of the engineer, but he has put into the hands of the people a process that is often made use of to foist on the public edibles not fit for human consumption. The chemist and the chemical engineer have discovered and manufactured anti-ferments until it has become necessary for the Government to ascertain by experiment how much chemical preservative the ordinary citizen could consume, and to require the labeling of manufactured foods. However, the labeling of our catsup bottles with the legend that one-tenth of one per cent of benzoate of soda is contained therein does not seem to deter its use. The rate of abuse now prevalent in some sections in storing undrawn poultry, and in exposing chilled meats in transit from storage to retail butcher shops will soon require the Government to regulate the cold-storage warehouse business. It is not apparent which resources the pure food law was intended to conserve. With the paternal form of government obtaining in some of the European

countries, the health of the individual is the paramount resource. With us, however, "civil and religious liberty" seems to include unnecessary exposure to disease. At the Conference in Washington the preventable disease problem was practically overlooked, perhaps from the fact that no trust seems to be operating in that field.

LAND

18 It is a question which is our chief natural resource, ourselves or our country. I have assumed the citizen as the first, and now come to the second, the land which we inhabit. In defence of this classification it is sufficient to mention the fact that the present development of the United States can be traced to small beginnings on our Eastern coast a few years ago, and while not within the province of the engineer to discant on the "rise and fall of nations," it may not be amiss to call attention to the necessity of keeping alive the sterling qualities and sound principles of the pioneers as a safeguard to our future progress as a republic. Our land may well receive our careful attention and its conservation be thoroughly studied. We shall be face to face in the near future with the fact that there is not sufficient land to support us at our present rate of growth and methods of living.

19 We will leave the Malthusian end of this problem to the political scientist and philosopher and direct our attention to the engineering side of the case. The accompanying tables show some of the more important items for the States and Territories. Foreign possessions

TABLE 4 INCREASE OF POPULATION

Year of census	Total population	Immigration	Per cent increase of population	Per cent of immigration	Foreign born	Per cent foreign born
1790	3,929,214	....	.....	....	....	....
1800	5,308,483	....	35.1	....	....	....
1810	7,239,881	....	36.4	....	....	....
1820	9,638,453	....	33.1	....	....	....
1830	12,866,020	....	33.5	....	....	....
1840	17,069,453	....	32.7	....	....	....
1850	23,191,876	....	35.9	....	2,244,602	9.7
1860	31,443,321	2,598,214	35.6	8.3	4,138,697	13.2
1870	38,558,371	2,314,824	22.6	6.0	5.567,229	14.4
1880	50,155,783	2,812,191	30.1	5.6	6.679,943	13.3
1890	62,622,250	5,246,613	24.9	8.4	9,308,104	14.8
1900	75,568,686	3,687.564	20.7	4.8	10,460,085	13.7

TABLE 5 COMPARISON OF URBAN POPULATION AND AVAILABLE FARM LAND

Year of census	Urban population	Per cent of urban	Number of farms	Total acres	Average acres per farm	Per cent increase of farms
1790	131,472	3.4	....	....	.....	....
1800	210,873	4.0	....	....	.....	....
1810	356,920	4.9	....	....	.....	....
1820	475,135	4.9	....	....	.....	....
1830	864,509	6.7	....	....	.....	....
1840	1,453,994	8.5	....	....	.....	....
1850	2,897,586	12.5	1,449,073	293,560,614	202.6	....
1860	5,072,256	16.1	2,044,077	407,212,538	199.2	41.1
1870	8,071,875	20.9	2,659,985	407,735,041	153.3	30.1
1880	11,318,875	22.6	4,008,907	536,081,835	133.7	50.7
1890	18,272,503	29.2	4,564,641	623,218,619	136.5	13.9
1900	24,992,199	33.1	5,739,657	841,201,546	146.6	25.7

In the year 1900, on the basis of 4000 and over, the percentage of urban population was 37.3.

are not included, as they do not enter into the Problem except as disturbing elements, and it is to be hoped that the franchise will not be extended to them. We must fight out our political differences at home and not wait for returns from the Philippines to know who is to be our next President.

20 Texas became one of the United States in 1845. If we assume the growth in population of the States and territories from the year 1850 to the year 1900 as an indication of the rate of growth which we may expect, that is, judge the future by the past, we can develop

TABLE 6 AGRICULTURAL POPULATION

Year of census	Population engaged in agricultural pursuits	Per cent of total population	Average value of farms per acre	Per cent increase in value
1880	7,713,875	44.3	$22.72	36.2
1890	8,565,926	37.7	25.81	32.0
1900	10,381,765	35.7	24.39	27.6

a formula that fairly represents the case. Representing the population at any time, T years subsequent to 1850, by P, we find that the expression:

$$\operatorname{Log} P = 1.702 (\log T - 0.897)$$

gives the approximate results shown in Table 7.

21 We see that the formula gives results corresponding with the census for the years 1850, 1890, and 1900. The computed results

TABLE 7 COMPARISON OF COMPUTED AND ACTUAL RATES OF GROWTH

Year	Population as shown by census, millions	Population as given by formula, millions	Error of formula, millions excess
1850	23	23	1
1860	31	32	2
1870	39	41	2
1880	50	52	....
1890	63	63	....
1900	75	75	....

for 1860, 1870, and 1880 are high, but the effect of the Civil War may be assumed to be responsible for a large part of the loss. Now *if* this formula holds good, as a rough approximation, for the next 150 years we may expect the growth shown in Table 8.

TABLE 8 ESTIMATED FUTURE POPULATION OF THE UNITED STATES

Year	Estimated population, millions	Estimated density per square mile	Year	Estimated population, millions	Estimated density per square mile
1[illegible]10	[illegible]	[illegible]0	1960	168	57
[illegible]	10[illegible]	35	19[illegible]0	186	63
1[illegible]0	11[illegible]	40	1[illegible]0	202	68
[illegible]0	1[illegible]4	45	19[illegible]0	225	76
[illegible]	[illegible]50	51	[illegible]000	245	83

22 The formula is, in my opinion, conservative and gives results that will probably be exceeded up to 1950. Beyond that time the reverse may be true. In round numbers, we may expect a population of 150 000 000 by the year 1950 and at the end of the present century we will be near the 250 000 000 mark. Our development will be both agricultural and industrial, and our limiting density of population will be governed by the ability of succeeding generations to compete in the markets of the world. A superficial study of the data will show that while our density will not become excessive during this century, we will nevertheless have to change our present extravagant pioneering methods of working and living.

23 Free trade would result in rapid changes in density of population, lowering the figures for the manufacturing states and raising them for the agricultural states. This problem is not for the Engineer, however, but he will form a part of the hegira while the statesmen are solving the tariff question.

TABLE 9 DENSITY OF POPULATION OF THE NEW ENGLAND STATES

Indicating the possibilities of an industrial development when the market for manufactured goods is protected from foreign competition

States	Total area Square miles	Water area Square miles	Land area Square miles	Population	Density per square mile
Maine	33,040	3,145	29,895	694,466	23.2
New Hampshire	9,305	300	9,005	411,588	45.7
Vermont	9,565	430	9,135	343,641	37.6
Massachusetts	8,315	275	9,040	2,805,346	348.9
Rhode Island	1,250	197	1,053	428,556	407.0
Connecticut	4,990	145	4,845	908,420	187.5
Totals and averages			62,973	5,592,017	174.98

TABLE 10 RATE OF GROWTH OF THE NEW ENGLAND STATES

State	1790	1800	1810	1820	1830	1840
Maine	3.2	5.1	7.7	10.0	13.4	16.8
New Hampshire	15.8	20.4	23.8	27.1	29.9	31.6
Vermont	9.4	16.9	22.9	25.8	30.7	32.0
Massachusetts	47.1	52.6	58.7	65.1	75.9	91.8
Connecticut	49.1	51.8	54.1	56.8	61.4	64.0
Rhode Island	63.4	63.7	70.9	76.6	89.6	100.3
Average	31.3	35.1	39.6	43.6	50.2	56.1
	1850	1860	1870	1880	1890	1900
Maine	19.5	21.0	21.0	21.7	22.1	23.2
New Hampshire	35.3	36.2	35.3	38.5	41.8	45.7
Vermont	34.4	34.5	36.2	36.4	36.4	37.6
Massachusetts	123.7	153.1	181.3	221.8	278.5	348.9
Connecticut	76.5	95.0	110.9	128.5	154.0	181.5
Rhode Island	136.0	160.9	200.3	254.9	318.4	407.0
Average	66.6	83.3	97.4	116.4	141.9	175.0

24 The figures are given to emphasize the fact that we have built up a condition in the United States that will require very careful handling to avoid disaster. The tariff has built up the trusts, and the trusts have built up the country, and the change from present conditions must be made slowly to avoid destruction.

25 The density of population of Germany for the year 1900 was 270 per square mile and it has been steadily increasing since that time. A comparison of this figure with the density of population of the

United States will convince the student that the German nation long ago solved most, if not all, of the conservation problems brought to our attention by the President. I venture to suggest that we might make progress by ascertaining the secret of German frugality and prosperity rather than by compiling masses of figures to prove that which is well known, viz: that we are wasting the resources of nature like a true prodigal son.

THE FOREST

26 One of the resources which the pioneer finds at hand and available for immediate use is the forest. It was necessary in many cases to clear away the primeval forests in order to render the land suitable for habitation, and this clearing had to be done at the minimum expenditure of labor. At present, however, the situation is very different. We are consuming over eight times as much lumber per capita as is used in Europe and our timber supply in the older parts of the country has been exhausted. It is high time we were taking thought for the future and making provision for a supply of timber for our successors. A good example of what may be accomplished in this line is to be found in Germany. Our own national Government has been making well directed efforts in this direction, so far as the public lands are concerned, but the states must each work in their respective domains in order to accomplish the best results. The clearing of land for farming is not criticised, but the unnecessary waste of timber resulting from an inordinate greed for gain (stimulated by a tariff) is the thing that needs checking. At this stage of the problem we begin to come into contact with the position of the engineer (I use the word in its broad sense) in relation to this natural resource. He has designed and built the machinery that has made the large production of lumber possible. The slow whip-saw and broadaxe methods of our forefathers have given way to the "shot gun feed," and any ordinary saw-mill will turn out more lumber in a day than the "Pilgrim Fathers" could have produced in a year.

27 The question that the engineer faces in private practice is how to increase the output and decrease the cost per thousand feet board measure. I have personally devised ways and means of *increasing* the fuel consumption of the power plant of a large saw mill, as a means of saving in the operating expenses of the mill. The problem, so far as the mill was concerned, was to produce lumber at the lowest price per thousand feet. A condition, and not a theory, confronted the Engineer. The alternative of meeting competition or

going out of business was the problem in this case as in many others, and this same test, under our system of government, is the force that will conserve those of our resources which fall in the class designated by the President as renewable.

28 Some of our manufacturing concerns using timber as a "raw material" are now, and have been for some time past, taking necessary precautions to insure a continuity of business existence. The preservation of forests for other purposes than as a source of supply for timber is "another story," and the questions involved are being worked out by the Bureau of Forestry, under the able direction of Gifford Pinchot. The reservation of forest lands by the Government needs careful handling to insure the protection of the citizen and to see that our timber supply is not captured *en masse* in the future by consolidated capital. A large surplus of capital or labor materials, generally makes trouble, and care must be taken to see that the national government does not lay foundations that may be used for a timber trust of gigantic proportions.

29 The waste of timber in the process of manufacture is at present as high as 75 per cent in some cases, and this waste is not counted from the log, but from the dimension lumber. Why is it that an English firm can sell shuttles and spindles in this country, in the face of a tariff? They do not waste anything, and the list of by-products made by them from scrap lumber would stagger a professor. A study of this problem for a New England concern, however, indicated that until the price of logs went up and the price of labor came down, by-products were not profitable undertakings in that locality.

30 The first action reserving public forest lands was due to the Act of Congress of 1891. Since that time the movement has progressed until we now have 150 National Reservations in the United States (See Table 11).

TABLE 11 FOREST RESERVATIONS

States	Acres	States	Acres
Arizona	9,422,125	Oklahoma	60,800
California	22,278,631	Oregon	16,463,535
Colorado	15,748,772	South Dakota	1,263,720
Idaho	20,336,427	Utah	7,127,339
Kansas	97,280	Washington	12,065,500
Montana	20,402,663	Wyoming	9,020,475
Nebraska	556,072		
Nevada	2,248,999	Total	142,972,855
New Mexico	8,279,584		

31 Our present supply of standing timber is estimated by Herbert M. Wilson at about 1 400 000 million ft. board measure; the annual "cut" at 100 000 million, a rate that will exhaust the supply in 14 years. We use per capita per year about 500 ft. board measure, as against an average of about 60 ft. for Europe. Our use of timber in house building not only consumes our supply but entails enormous expense for insurance and fire protection. Estimates of the fire tax for the year 1907 run about $2.50 per capita, as against an estimated average of $0.35 for Europe. The total cost for fire losses and for fire protection is not known, but the Government is at work on the problem and may be able to give some estimate in the next census report.

32 Our suggestion for reducing the consumption of timber is by the substitution of fibre products. This is now done to a large extent by the use of paper, and the use can be increased. In Germany peat products are used to replace wood where practical. The waste of fibre-producing material at present is enormous and the sources of future supply practically undiscovered.

WATER

33 Following the President's classification of our natural resources we turn to the one great natural phenomenon which makes our country suitable for the growth of a great nation and the development of a great people. The thing we all must have is water, and for that we are dependent on rainfall. Those of us who have not experienced the hardships of a scant and precarious water supply can have no appreciation of the bounties nature has lavishly scattered through this section of the country, nor of the local conditions created by deficient rainfall in the irrigation regions. In this as in other matters we acquire true knowledge only by hard knocks and bitter experience.

34 The Irrigation Engineer has to deal with these problems, and to aid in the conservation of the water resources of the country. The people of the irrigation districts, however, are the true promoters of the conservation idea as applied to water, and have made laws which have as their foundation the beneficial use of the water. Necessity has been the teacher and the people have learned their lessons well: as our resources become scarce necessity will teach us the same lesson, and eventually the doctrines of appropriation and application to beneficial use will become general, for the necessities.[1]

[1] For the luxuries our present methods will probably remain unchanged.

35 Our present laws and methods of irrigation are of comparatively recent date and are in the formative period, but the beginnings of the art antedate history. Irrigation was practiced by the peoples of ancient China and India and is mentioned in the early Biblical writings. It was evidently practiced by the inhabitants of the arid regions of this country also in prehistoric times. Life could not have been supported without it. Our general practice and methods were first derived from Mexico and show the results of Spanish law and practice. In the United States, irrigation was first practiced by the Mormons. In some parts of the country, irrigation followed mining, but the underlying principles governing the right to use water were fixed by pioneer necessities and followed Mexican practice.

36 The first effort of the Irrigation Engineer must be to divest himself of his unconscious prejudice in favor of the English law of riparian rights, which is set aside under the conditions which call the irrigation works into existence. The State claims the fee, and grants only an easement known as a water right. Such an easement may be acquired: *first,* by an appropriation, a notice of which is required to be posted in some states, while a mental process on the part of the appropriator seems sufficient in others; *second,* by the beneficial use of the water. The appropriator acquires the right to only as much water as he can use for beneficial (?) purposes and not the right to waste water. The process of law required by the State must be complied with and when a decree is issued as a result of the entire process the appropriator becomes possessed of an "adjudicated water right" which is to all intents and purposes property, but which may be abandoned and lost by non-use. Decreed water rights are classified as to priority, and the principle of "first in time is first in right" is strictly enforced. The appropriators of water on a stream are entitled to water in the order of their priorities, which bear the date of the appropriation, and in times of scarcity the last appropriator is the first to be shut down. This shutting down of headgates continues with a growing deficiency of water until in cases of extreme drought the only ditch operating will be the oldest priority. It is the operation of this principle that has led to the storing of water in times of plenty for use during the latter part of the season when water is scarce. The right to take water from the stream for direct application to land during the irrigating season is called a ditch right, the water being conducted from the stream by means of ditches and flumes. Where the water is first conducted into a reservoir either for use during the same season or to be held from one season to another, the right is called a

storage right. Some storage rights are for the non-irrigating or storage season, and others are for the storage of early floods for use later in the same season. In general, water rights are either ditch rights or storage rights. Water rights are classified in accordance with the importance of their use, viz:

Domestic rights, including municipal water supply.

Irrigation rights, ditch and storage.

Power rights.

37 These rights rank as to priority, independent of classification; that is, a power right of the lowest class may have the oldest priority and the first right to take water. A power right, however, can be condemned for a higher use, such as irrigation or domestic use, and in turn an irrigation right may be condemned for municipal use, but the rule does not work in the reverse order.

38 The amount of water taken by an appropriator is regulated and controlled by a head-gate built in the bank of the stream where the water is drawn out, and under the charge of State officials who set them to regulate the rate of flow from stream to ditch. In early days, ditch appropriations were made in inches of water, but the latter appropriations, and most of the priorities, are recorded in cubic feet of water per second of time. Some appropriations call for as much water as will flow through a ditch of given dimensions and grade. The inch of water, variously known as miner's inch, sluicing inch and irrigator's inch, is used to designate the rate at which water flows through the head-gate or measuring box. In various states and localities the "inch" represents different rates of flow. While it is an approximate measure, the inch is, nevertheless, a very convenient unit. Many outstanding contracts have the inch as the unit of measurement and decrees are occasionally issued in which the right to water is limited by the number of inches of water decreed. At present the tendency of the engineering profession is to use the "second-foot" and the "acre foot" as the units of rate and quantity. The inch is a handy unit for the irrigator and he will continue to use it, but the engineer must adapt himself to the location and ascertain the rate of flow represented by the local inch. The following memoranda on the inch of water in different states are given for the benefit of members who may need them at some future time:

a The Colorado Statute defines the inch as follows: "Every inch shall be considered equal to an inch-square orifice under a 5 in. pressure and a 5 in. pressure shall be from the top of the orifice of the box put into the bank of the ditch to the surface of the water."

b The Idaho Statute prescribes: "The amount of water that will flow through an orifice one inch square with a 4 in. pressure above the center of the orifice."

c The North Dakota Statute is: "The Miner's Inch shall be regarded as $\frac{1}{50}$ cu. ft. per second in all cases except when some other equivalent of the cubic foot per second has been stated by contract, or has been established by actual measurement or use."

d In Utah: "Standard measurement of flow, one cubic foot per second, known as the second-foot. Standard measurement of volume the acre-foot."

e The Wyoming Statute is: "A cubic foot per second of time shall be the legal standard for the measurement of water in this State, both for the purpose of determining the flow of water in natural streams and for the purpose of distributing the water thereof."

f Montana: A new act provides that "the cubic foot per second shall be the standard of measurement; 100 miner's inches, equivalent to $2\frac{1}{2}$ cu. ft. per second, not to affect measurements heretofore decreed by court."

g Nebraska: Every inch considered to be one inch square orifice under a 4 in. pressure, and a 4 in. pressure shall be from the top of the orifice in the measuring box to the surface of the water. "Boxes must be 6 in. in height, except where less than 12 in. are delivered; have descending slope $\frac{1}{8}$ in. to the foot and 14 ft. long; 50 miner's inches under 4 in. pressure equivalent to 1 cu. ft. per second of time.

h California: The following is from the San Francisco Post, of the late 70's: A miner's inch of water is a quantity that will flow through an inch aperture with a free discharge and under a constant pressure of 6 in. above the top of the opening. An aperture of 12.25 in. by 15.75 in., under a pressure of 6 in. above the top of the opening, will discharge 200 in., and is the basis of all measurements where water is retailed in small quantity in the States of California and Nevada."

39 It is customary to express the ratio between the inch and the second-foot as the number of inches which equal a second-foot. The values generally used are:

Colorado, miner's inch.

50 in. = 1 sec-ft; Statutory inch: 38.4

California, miner's inch:

50 in. = 1 sec-ft.

Arizona, miner's inch:

40 in. = 1 sec-ft.

New Mexico, miner's inch:

50 in. = 1 sec-ft.

The inch varies from 50 to the second foot to about 34 to the second foot and the engineer must ascertain the inch in use in the locality for which he is designing work.

40 In some states the duty of water is prescribed by law. By this is meant the duty which a given flow or volume is expected to perform and this is a measure of the quantity which the appropriator is permitted to take for his own use. In states with codes modeled after that of Wyoming, the rate of flow is fixed from 1 sec-ft. for 50 acres to 1 sec-ft for 70 acres. In Colorado the old standard seems to have been 1 in. per acre, and present practice tends to a flow of 1.44 sec. ft. for 80 acres.

41 Experience has demonstrated the potentiality of the soil of the arid regions, proving that with proper handling good crops can be raised and money made by the farmer. In the Sacramento and San Joaquin valleys there is an irrigated area of 250 000 acres and a population estimated at 300 000 where the population 15 years ago did not exceed 60 000.

42 As an example of what is being accomplished in Colorado, the following figures may be of passing interest to us and of value to the Irrigation Engineer.

43 The most striking feature of the conservation of rainfall is the impounding of the surplus water of one season against the deficiency of another. The work of the Western pioneers has accomplished wonders in making waste places habitable and in building up a territory otherwise barren and unproductive. The Reclamation Service has done good work in opening up for settlement a large amount of land. Table 16, compiled from the Governments records, shows the work in hand.

44 The work accomplished by the Reclamation Service is a good example of the conservation idea properly applied, and the example should be followed by States and individuals where practicable. The work of the Government in this line can not be over-estimated; it adds to our resources and that in a way that puts the land in the hands of the farmer.

Irrigation Statistics of Colorado 1906

TABLE 12 EXTENT OF IRRIGATION

	Division No. 1	Division No. 2	Total
Length of Main Ditch, Miles	3314	2840	6154
Length of Laterals, Miles	1927	2147	4074
Water used, Acre feet	1,228,821	1,607,292	2,836,113
Crops Irrigated			
Alfalfa	225,495	136,464	388,959
Natural Grasses	204,907	49,424	254,331
Cereals	328,357	67,051	395,408
Orchards	12,786	14,453	27,239
Market gardens	18,132	2,962	21,094
Potatoes	43,748	799	44,547
Sugar beets	81,375	46,668	128,043
Other crops	34,937	31,913	66,850
Total acres irrigated	921,675	376,734	1,298,409
Total acres that can be irrigated	1,310,125	533,737	1,843,862
Average water applied			
Acre feet per acre			

TABLE 13 YIELD OF IRRIGATED LAND

Boulder County

Fruit	Average yield per acre	Average selling price	Crop value per acre
Apples	300 boxes	$0.90 per box	$270
Cherries	300 crates	2.00 per crate	600
Blackberries	3500 quarts	0.15 per quart	525
Raspberries	4800 quarts	0.12 per quart	596
Strawberries	5000 quarts	0.10 per quart	500

Denver City and County

Apples	300 boxes	$0.90 per box	$270
Plums	500 crates	0.50 per crate	250
Cherries	350 crates	2.00 per crate	700
Blackberries	1800 quarts	0.20 per quart	360
Raspberries	4000 quarts	0.15 per quart	600
Strawberries	2000 quarts	0.10 per quart	200

Jefferson County

Apples	300 boxes	$0.50 per box	$150
Plums	400 crates	0.50 per crate	200
Cherries	350 crates	2.00 per crate	700
Blackberries	1600 quarts	0.20 per quart	320
Raspberries	3200 quarts	0.10 per quart	320
Strawberries	2400 quarts	0.10 per quart	240

These statistics are from the report of Thos. W. Jaycox, State Engineer.

TABLE 14 SUGAR BEET RECORDS

1907

Acres	Net Tons of beets	Tons per acre	Value of crop	Crop value per acre
16.0	264.70	16.6	$1329.80	$83.11
20.7	393.70	19.0	2000.79	96.65
17.8	541.50	30.4	2633.11	147.93
52.7	1250.00	23.9	6299.57	119.55
30.2	458.60	15.2	2303.44	76.30
9.7	258.40	26.6	1291.79	133.17
48.1	1025.50	21.3	4996.88	103.89
35.5	542.40	15.3	2711.77	76.39
24.0	485.00	20.2	2425.00	101.04
25.0	521.00	20.8	2655.28	106.21
47.0	877.60	18.7	4466.75	95.04
35.0	1028.70	29.4	5143.43	146.95
10.0	301.00	30.1	1504.61	150.46
338.0	5975.60	17.6	29877.90	88.40
47.2	828.40	17.6	4022.85	83.75
17.0	444.10	26.1	2218.99	130.53
37.0	816.70	22.1	4143.73	112.00
50.0	1012.30	20.2	5061.45	101.23
860.9	17025.20	391.10	$85087.14	$1952.60
	Average	21.7		108.46

Average cost of producing is about $35 per acre.

TABLE 15 CROPS WITHIN DRIVING DISTANCE OF DENVER

1907

	Acres	Yield	Selling Price	Value of crop per acre	Net per acre
Strawberries............	14	1600 crates	$1.40 per crate	$588.00	
	25	1600 crates	2.00 per crate	640.00	$464
Raspberries*	12	500 crates	2.25 per crate	562.50	....
	24	1000 crates	1.50 per crate	375.00	....
	35	1600 crates	1.50 per crate	500.00	....
Cabbage, average crop† ..	......	20 tons	0.75 per hundred	300.00	....
Onions.................	......	....	1.50 per sack	300 to 450	180 to 270
Late cauliflower.........	12	....	.025 per pound	300.00	200
Celery..................	1	3000 dozen	.27 per dozen	810.00	600
Turnips................	1	20 tons	12.00 per ton	240.00	165 to 190
Parsnips................	1	20 tons	15.00 per ton	300.00	250

* Average cost of picking, crating and marketing $0.55 per crate
† Average cost of production, marketing, etc., $60 per crop
These statistics are from the report of Thos. W. Jaycox, State Engineer.

TABLE 16 AREAS, COST, EXPENDITURES, ETC., ON ENTIRE PROJECTS OR ON SUCH UNITS AS IT IS EXPECTED TO COMPLETE BY 1911

Location	Project	Area in acres	Estimated cost	Estimated expenditure to December 31, 1907	Per cent of completion
Arizona	Salt River	210,000	$6,300,000	$4,362,100	69.2
California	Orland	30,000	1,200,000	16,900	1.4
California, Arizona	Yuma	100,000	4,500,000	1,876,700	41.7
Colorado	Uncompahgre	140,000	5,600,000	2,900,000	51.8
Colorado	Grand Valley	50,000	2,250,000	9,750	0.4
Idaho	Minidoka	160,000	4,000,000	1,839,700	46.0
Idaho	Payette-Bois	100,000	3,000,000	1,381,500	46.5
Kansas	Garden City	8,000	350,000	282,000	80.5
Montana	Huntley	30,000	900,000	796,400	88.4
Montana	Milk River, including Saint Mary	30,000	1,200,000	314,800	26.2
Montana	Sun River	16,000	500,000	344,100	69.0
Nebraska, Wyoming	North Platte	110,000	3,850,000	2,797,300	73.0
Nevada	Truckee-Carson	170,000	4,800,000	3,804,600	79.2
New Mexico	Carlsbad	20,000	640,000	579,400	81.5
New Mexico	Hondo	10,000	370,000	358,600	97.0
New Mexico	Leasburg	10,000	200,000	167,900	83.9
New Mexico, Texas	Rio Grande	160,000	8,000,000	53,200	0.6
North Dakota	Pumping, Buford, Trenton, Williston	40,000	1,240,000	519,600	41.9
Montana, North Dakota	Lower Yellowstone	66,000	2,700,000	751,850	64.9
Oregon	Umatilla	18,000	1,100,000	765,500	69.6
Oregon, California	Klamath	120,000	3,600,000	1,305,080	36.2
South Dakota	Belle Fourche	100,000	3,500,000	1,281,900	36.6
Utah	Strawberry Valley	30,000	1,500,000	418,700	27.9
Washington	Okanogan	8,000	500,000	372,180	74.4
Washington	Sunnyside	40,000	1,600,000	481,180	30.7
Washington	Teiton	24,000	1,500,000	565,420	37.6
Washington	Wapato	20,000	600,000	5,220	8.7
Wyoming	Shoshone	100,000	4,500,000	2,313,990	51.5
		1,910,000	$70,000,000	$30,665,570	

From Blanchard

45 Irrigation projects are not proper subjects for the speculator. While there is a large increase in values resulting from a properly executed irrigation undertaking, the increase in value is not an "unearned increment:" the farmer must earn it. The fact that irrigation works are necessary for cultivation does not change the status of the land from that of farm land in general. The real development and improvement must be made by those fitted to till the soil and become permanent inhabitants of the reclaimed land. The inability

to see this simple truth has caused numerous speculators to lose money and has thrown a large number of highly advertised irrigation schemes into bankruptcy. Speculative interests will take desperate chances and trust to the ability of sales agents and glaring advertisements to "unload" before the inevitable failure comes. The reclamation act has avoided this rock, on which so many private undertakings split, by limiting the amount of land to each settler, and the cost per

TABLE 17 GRAZING, WOODLAND, FOREST, DESERT AND IRRIGATED LAND, AND EXTENT OF WATER SUPPLY IN THE WESTERN PUBLIC LAND STATES

States and Territories	Millions of Acres							
Arizona	72	38	14	5	15	0.2	0.2	2
California	99	20	19	19	20	15.0	1.5	17
Colorado	66	40	9	5		2.0	1.2	8
Idaho	54	20	12	11		1.0	0.5	5
Montana	93	56	7	12		1.0	0.8	11
Nebraska	49	25	2			22.0		2
Nevada	70	42	6	1	20	1.0	0.5	2
New Mexico	78	57	12	4		0.5	0.2	4
N. Dakota	45	38	1			6.0		2
Oregon	60	18	9	19		5.0	0.3	3
S. Dakota	49	38	1			10.0		2
Utah	52	18	16	4	10	2.0	0.5	4
Washington	43	9	13	13		2.0	0.1	3
Wyoming	62	39	3	4	5	1.0	0.5	9

TABLE 18 SWAMP LANDS

States	Area in square miles	States	Area in square miles
Florida	29,000	Indiana	1,250
Louisiana	15,000	New Jersey	900
Western States	10,000	New Hampshire	600
Arkansas	9,000	Massachusetts	500
Mississippi	9,000	Maryland	500
Michigan	7,500	Iowa	400
Minnesota	6,000	Vermont	400
Wisconsin	4,500	Nebraska	400
Maine	4,000	North Dakota	375
North Carolina	3,750	South Dakota	375
Georgia	3,750	Kentucky	350
Illinois	3,500	Pennsylvania	300
Missouri	3 000	Kansas	250
South Carolina	2,750	Connecticut	100
New York	2,500	Delaware	50
Alabama	1,750	Rhode Island	30
Virginia	1,600		
Tennessee	1,250		125,880
Ohio	1,250		

acre of the project, and by requiring the actual use and improvement of the land to acquire title. The act recognizes the fundamental principle of appropriation in the following language:—"That the right to the use of water acquired under the provisions of this act shall be appurtenant to the land irrigated, and beneficial use shall be the basis, the measure and the limit of the right." This provision of the act has been carefully drawn for the protection of the farmer and the confusion of the speculator.

46 The States that have lands subject to their control should follow this good example by adopting laws controlling the development of irrigation projects and exercise stringent control and supervision over water rights and districts subject to floods. In fact, the General Government should assume supervisory control over all projects for the development of lands liable to disastrous flooding. Table 17, taken from the Government records, shows in condensed form the general situation and the work remaining to be done.

SWAMP LANDS

47 Another field of operation is the reclamation of swamp lands. A little work is in progress in this line, but compared with the total amount of work to be done, it is not worth mentioning. Table 18, compiled from records of the Geological Survey by Herbert M. Wilson, shows the field for work.

POWER—WATER

48 In connection with irrigation and municipal water supply in arid and semi-arid regions is the closely related problem of power. In all the states in which appropriation of water is made, the appropriation for power purposes is recognized. As a general proposition, the development of a water-shed for irrigation and power purposes, jointly, is not practicable. In sections of the country where coal is cheap, the power phase of the water supply question will lie dormant until the cost of coal reaches a point that makes the installation of hydro-electric plants feasible from a money standpoint. There seems to be a hypnotic power attached to hydraulic power schemes that causes promoters and investors to lose sight of the fact that the real criterion is fixed charges *versus* operating expenses. It may also be the idea that they are going to get something for nothing which warps

judgment. Be that as it may, the fact remains that over-enthusiasm in the direction of hydraulic power plants has caused much trouble and loss of money. In locations such as the Pacific Coast, with coal at about $14 per ton, the hydro-electric plant finds its true habitat, but in the vicinity of coal mines, where cheap fuel prevails, the steam-driven plant is the present solution. So far as the conservation of water power is concerned, much may be said, but the problem, involving as it does the fundamental question of ownership by the individual, the state or the nation and the further legal question of riparian rights as opposed to appropriation, is one that it will require much study and many legal battles to solve.

49 The water power problem does not form a part of the conservation problem. The question is not one of the waste of water and the resource does not fall into either of the classes into which the President divided our natural resources. It is neither renewable nor non-renewable and its use does not diminish the supply. The question involved is one of ownership and the real conservation will be effected by legislation that will protect the public from the loss of valuable rights. The improvement in long distance transmission from the 10 miles of 10 years ago to the 200-mile lines of to-day makes water power available over large districts. In California four power companies, with an aggregate capital of some fifty millions of dollars control thirty hydro-electric and steam power plants. In the entire state about 250 000 h.p. is in operation under private control.

50 Mr. Lindsay states that there is a potential development of 800 000 h.p. on four rivers in the northern part of California that are under private control and that but 20 000 is utilized, the balance being tied up by speculative interests. Heretofore Congress has required no compensation for water power grants and during the last ten years has handed over to promoters and speculators 33 such grants *gratis*. The same authority states that of about 16 000 000 h.p. now in use in the United States, less than $\frac{1}{4}$ is from water power and 1 600 000 h.p. is going to waste over Government dams. The total water horse-power available for immediate use is given as 25 000 000.

51 I am well aware that the Waterways Commission was "tacked" on to the Conservation movement, but that was because Congress and the President had some differences of opinion regarding appropriations, and the water power question was also included. A strong veto message would stop a water power scheme for which the grantees were not required to render a just equivalent, without the consideration of a National Commission on Conservation of Natural Resources.

52 So far as our Western rivers are concerned, time has shown that the method of transportation which gives the lowest total cost of moving freight is the one that gets the business. For short hauls between river towns water transportation is cheaper and quicker than railways, for ordinary freight, but the advantage disappears as the distance increases. For export shipments, from St. Louis, the additional expense for insurance and interests on cargoes, with the cost of returning empty barges, has proved too great a handicap for river transportation to overcome. These items of expense are not materially lessened by river improvement, and it is not readily apparent how any depth of channel will materially lessen them or reduce fixed charges.

53 As the country becomes more thickly settled our rivers will have to be improved and controlled, and the sooner this work is inaugurated on proper lines the less will be the total cost of the work, but to put forth unsound arguments and to use the public works of the country to influence votes is not conducive to the continued development of our Republic. There is, at present, a strong tendency towards bureaucratic development that is inimical to the successful continuity of our form of Government. The waterways movement is not free from political influences and The American Society of Mechanical Engineers will do well to keep all political questions out of its proceedings.

POWER—COAL

54 Following logically after water-power is the problem of conserving our present great source of light, heat and power, *coal*. To the discovery and use of coal is to be attributed, more than to any other cause, the rapid development of the United States. It is the primary source of the power that has moved the wheels of commerce and manufacture. The rate at which we are consuming this heritage from Nature is sufficient evidence of the necessity of an inquiry into the probable supply.

55 Mr. Wilson, of the U. S. Geological Survey, estimates that our present rate of increase in the consumption of coal indicates that our supply will be exhausted in about 200 years. Estimates in this field, as in other long range predictions, are to be taken, however, as an integration of our present available differential coefficient. The law of the curve may not be properly expressed by deductions from our present knowledge, and future observations may prove that we are

drawing conclusions from insufficient data, obtained at the apex of the curve. I well remember that our Professor of Mining Engineering explained to the class of which I was a member the uselessness of prospecting for coal in the Rocky Mountains. It is quite plain at this time that his data were insufficient. We now realize that the conclusions of a Conference on the Conservation of Whales, had one taken place in New Bedford some years ago, would have created unnecessary alarm and expense. While whales were an important item in that day and generation, the present civilization does not need them.

56 The coal problem is, however, one requiring some consideration. Coal once consumed can not be replaced, and the steadily increasing cost of fuel must be faced. We have in the United States prices ranging from less than $1 to over $14 a ton for coal. I know of a railway power house, in Illinois, where the coal costs about $0.70 a ton delivered on the grates. The only way to conserve our supply of coal is to use it as economically as possible.

57 In the economical use of coal we have two main questions, mining and burning. With our easily mined Western coals it pays to use "wasteful methods" and these mining methods will continue until there is a radical change in present conditions. The mine operator and his engineer must meet competition. They do not adopt mining methods in advance of the times for fear of the certain end of their coal mining operations in bankruptcy. Just so long as it pays to work a mine for the best coal only, this process wi l continue and the future will have to take care of itself. Which one of you, as householder or engineer, will put up with a poor run of coal, in order that posterity may have good coal? The departments of our Government demand the best grade and are not willing to take the "run of the mine." This means that the poor grades are pushed on smaller purchasers or "go over the dump." If the Government wishes to set an example in the conservation of the coal supply, let an effort be made to adjust the power plants and heating plants in Washington to burn the low grade fuel.

58 Why does not the doctrine of "first in time is first in right," so strenuously introduced and so vigorously supported in the case of "water rights," apply, and permit the present generation to mine as they choose and grant the same privilege to succeeding generations? Who knows but that in the development of the plans of the "Supreme Architect of the Universe" worlds and planetary systems have birth, youth, manhood, old age and death and that we are but a small part

of the ways and means for executing a very small part of the universal plan? Our boasted civilization and rapid progress may be an indication that the end is rapidly approaching.

59 The outlook for improvement in mining, so far as conserving the coal supply is concerned, without a consolidation of competitors is not promising. How to accomplish the desired result under our form of government with unlimited competition, is not readily apparent; and mining will continue as in the past, until the Statesman and law maker, in deference to the opinions of the people, make radical changes in our fundamental laws. The present waste of both coal and life, in mining, should be reduced to a minimum. Both wastes are due, primarily, to the same cause. The selling price of coal, unless trust-controlled, must be kept down to competition prices, and in the Illinois mines the miner takes desperate risks in order to reduce his percentage of dead work, and occasionally pays for the risk with his life. The unnecessary loss of life has been reduced in other countries and can be reduced in our country. It is due to an uncontrolled greed for gain. Personally, I am of the opinion that the doctrine of "appropriation and beneficial use" offers many advantages not now understood and appreciated, and that it should be, so far as practicable, applied to our remaining natural resources under public control.

60 The Mechanical Engineer is more interested in the use than in the mining of coal, but here again he is confronted with the ever-present problem of "making both ends meet" and while he can not afford to be far behind the times, he realizes that he, also, can not afford to lose money by getting too far ahead of the times. Our last 20 years of progress in electrical lines is a good illustration of the cost of a rapid improvement in the general state of an art, and many of our electrical undertakings are loaded with fixed charges which represent the sins and shortcomings of preceding plants, relegated to the scrap pile before they had earned a fraction of their cost.

61 For the production of power the gas engine and producer give promise of a large saving in coal. The best data at hand indicating the saving that may result in ordinary practice are in the report of tests conducted at the World's Fair of 1903 by the U. S. Geological Department. The condensed results of the tests are shown in the following tables, which represent as nearly as possible the conditions of ordinary practice.

62 At present the gas engine and gas producer are in the stage of development. In the slang of the engineer, there are still some "bugs" to be gotten out of the apparatus. As applied to blast fur-

TABLE 19 COMPARATIVE SUMMARY OF LEADING RESULTS OF COAL TESTS MADE UNDER THE BOILER AND IN THE GAS PRODUCER

Name of sample	Duration of Trial		Total Dry Coal Consumed per Hour*		Dry Coal Burned per Square Foot of Grate Surface per Hour		Water Evaporated from and at 212 deg. Fahr. per Pound Dry Coal	B.T.U. per Pound of Dry Coal Used		Electric Horse Power Delivered to Switch-Board		Total Dry Coal per Electrical Horse Power per Hour*	
	Steam plant	Gas producer plant	Steam plant	Gas producer plant	Steam plant	Gas producer plant†	Steam plant	Steam plant	Gas producer	Steam	Gas producer plant	Steam plant	Gas producer plant
	Hours	Hours	Pounds	Pounds	Pounds	Pounds	Pounds					Pounds	Pounds
Alabama No. 2	10.02	43.00	874	328.7	21.54	7.78	8.55	12,555	13,365	213.7	200.6	4.08	1.64
Colorado No. 1	9.97	30.00	722	341.7	17.80	7.56	7.21	12,577	12,245	149.1	200.2	4.84	1.71
Illinois No. 3	10.13	30.00	861	356.7	21.23	8.41	8.04	12,857	13,041	198.1	199.6	4.34	‡1.79
Illinois No. 4	10.02	30.00	938	348.5	23.13	7.96	7.27	12,459	12,834	195.4	198.4	4.80	‡1.76
Indiana No. 1	9.93	29.67	908	384.3	22.39	9.08	8.45	13,377	13,037	220.0	199.9	4.13	‡1.93
Indiana No. 2	10.13	7.00	832	312.0	20.51	7.13	8.02	12,452	12,953	191.0	201.0	4.35	‡1.55
Indian Territory No. 1	9.75	31.00	778	374.0	19.17	8.95	8.64	12,834	13,455	192.3	204.0	4.04	1.83
Kentucky No. 3	10.07	30.00	882	381.2	21.75	8.92	8.27	13,036	13,226	208.9	200.5	4.22	‡1.91
Missouri No. 2	9.98	4.33	1014	339.6	25.00	7.96	7.08	11,500	11,882	205.6	198.6	4.93	‡1.71
W. Virginia No. 1	9.98	24.00	768	315.6	18.94	7.36	8.95	14,198	14,396	196.7	200.4	3.90	1.57
W. Virginia No. 4	10.00	9.00	770	258.2	18.98	5.96	9.65	14,002	14,202	212.5	199.7	3.62	1.29
W. Virginia No. 9	10.00	6.33	721	320.1	17.78	7.60	10.90	14,616	14,580	208.2	201.1	3.46	1.59
W. Virginia No. 12	10.13	30.00	719	300.5	17.68	6.92	9.90	15,170	14,825	203.6	199.8	3.53	‡1.50
Wyoming No. 2	9.95	30.00	1075	416.5	26.51	9.50	5.92	10,897	10,656	182.0	201.2	5.90	2.07

* In gas producer plants this includes the coal consumed in the producer and the coal equivalent of the steam used in operating the producer.

† Coal actually consumed in producer only.

‡ Gas producer hopper leaked during these tests.

nace work and for running on natural gas the gas engine is giving results that indicate its ultimate success. In furnace work the gas engine uses about 40 per cent of the blast furnace gas consumed under boilers supplying steam to a first-class steam-blowing engine of the same capacity. This rate is confirmed by data from a gas engine driven dynamo and indicates that a saving of about 60 per cent in coal is possible by substituting gas engines for steam engines of the ordinary type. On natural gas the guaranteed performance of the gas engine is generally at the rate of a horse power on 10 000 B.t.u. This with "12 cent" gas, in the Joplin lead district of Missouri, will make the fuel cost per kw-hr. on the bus 0.15 cents.

63 With a going concern the operating cost of producing power is generally a small part of the total cost, and the coal cost is still smaller, so that such factors as fixed charges and reliability are very important in deciding the kind of power plant best suited to furnish power for the undertaking. The true solution is found when the cost of power per unit of output is a minimum and there is no diminution of output due to power-house causes. In designing plants, with a high labor and a low material market, the Engineer often finds the power plant which will produce a horse-power-hour with the smallest coal consumption to be the most expensive plant under operating conditions. I have in mind from my personal experience two illustrations of this. In one case a power plant and arrangement of machinery were used that would make the graduate Mechanical Engineer just from school smile in derision, and in the other case the power plant, put in at the request of the owner, who expressed a desire to assist in the improvement of the general state of the art, would delight the heart of a professor of thermo-dynamics. The relative amount of coal per horse-power in the two plants were about 4 to 1 yet the plant which used 5 lb. of coal per horse power caused competitors to consolidate for the purpose of reducing expenses while the plant that used $1\frac{1}{4}$ lb. of coal per horse-power fulfilled the desire of the owner, who is still contributing to the advancement of the art and boasting of coal economy. It would not surprise me, however, to get an order at any time to put in a steam plant and dump the gas plant in the scrap pile.

64 In the West our labor market is not yet abreast of the best steam engine practice, to say nothing of the gas engine, and we can only wait until high cost of material shall enable the labor market to furnish the skilled labor necessary to operate the higher grades of power plants.

65 With true British perversity, James Watt adopted 33 000 ft. lb per minute as the unit of power, and use has fastened this ungainly number on the profession. For this unit we have a good running mate in the German fahrenheit degree. The British thermal unit is the amount of heat required to raise the temperature of 1 lb. of water 1 deg. fahr. This amount of heat is equivalent to about 778 ft. lb. of energy, so that for practical purposes we have 2545 B. t.u. as the equivalent of our unit of work, the horse-power-hour.

66 A pound of coal, ranging from lignites to the best steam coal, will develop an amount of heat ranging from about 9000 thermal units for the lignites to 15 000 thermal units for the best steam coals. If we could utilize all the energy stored in the coal we could produce from 3.54 to 5.89 h.p.hr. per pound of coal.

67 With the steam power plant as a means of transforming the potential heat energy of the coal into power we have, first, the losses due to the boiler plant, which with the most efficient plants will run at least 20 per cent and from that up to 50 per cent and more. Under every-day conditions a loss of 40 per cent may be expected. The next loss is due to the use of steam as a working medium. The theoretical efficiency possible is found by dividing the range of working temperature by the absolute temperature. With the best steam engines a thermo-dynamic efficiency of over 20 per cent is seldom obtained, so that, of the energy of the coal used in a steam power plant we can expect at the best no more than the equivalent of 15 per cent of the energy of the coal. The best efficiency to which I can personally certify is 16 per cent, and that with Illinois coal.

68 In one instance of good practice the heat delivered to the engine was accounted for as follows:

	Per cent
Converted into work	19.6
Radiated from engine	0.76
Rejected to condenser	74.6
Lost in drains from engine	1.71
Returned to boiler	3.33
Total	100.00

69 Good average conditions, however, may be stated for the entire plant about as follows:

	Per cent
Smoke stack gases	22
Radiation from boiler, etc.	7
Radiation from engine and pipe	4
Rejected to condenser	57
Converted into work	10
Total	100

70 Mr. H. G. Stott, Member of The American Society of Mechanical Engineers, estimates the average heat distribution in the power house as shown in Table 20. We may assume that with a good steam generating station we convert but ten per cent of the heat stored in the coal into electricity, on the bus-bars. Further losses due to distribution and conversion, in various ways, to light and power occur so that we get but little of the potential energy provided for our use by a wise and beneficent Nature. Surely, if our ecclesiastical brethren maintain that the storage of coal is a manifestation of Divine Providence, the present inventions for utilizing it must have emanated from his Satanic Majesty.

TABLE 20 AVERAGE HEAT DISTRIBUTION IN THE POWER HOUSE

	Per cent	Per cent
Heat in the coal		100
Loss in ashes	2.4	
Loss in stack	22.7	
Loss from boiler radiation and leakage	8.0	
Returned by feed water heater		3.1
Returned by economizer		6.8
Loss in pipe radiation	0.2	
Delivered to circulator	1.6	
Delivered to boiler feeder	1.4	
Leakage and high pressure drips	1.1	
Heating	0.2	
Loss in engine friction	0.8	
Delivered to small auxiliaries	0.4	
To house auxiliaries	0.2	
Radiation from engine	0.2	
Rejected to condenser	60.1	
Electrical losses	0.3	
Totals	99.6	109.9
Delivered to bus-bar		10.3

71 Another subject which is now engaging a great deal of the attention of advanced engineers is the process of converting coal into

gas in an apparatus called a producer and then burning the gas in the cylinder of a gas engine. This method gives a greater range of working temperature and consequently an outlook for greater efficiency of conversion of coal into work. With the first step of the process, however, the result will average in practice about the same as with the boiler, that is, there is a practicable efficiency of about 70 per cent. In the second step, that is, the conversion of the simple producer gas into power, the outlook for realizing the full benefit of the greater range of working temperature seems to be offset by the cooling necessary to maintain the working parts of the engine. The customary guarantee on gas engine performance is 1 h.p. on 11 000 B.t.u. or about 23.2 per cent efficiency, so that with simple producer gas we have about the same result as with the best steam engine, that is, about 15 per cent of the heat stored in the combustible converted into work.

72 It is quite safe to assume that with our best methods we can not expect more than 15 per cent of the heat value of the coal to be converted into work in the power house. With an efficiency of dis-

TABLE 21 LOSSES IN THE CONVERSION INTO ELECTRICAL ENERGY OF THE POTENTIAL HEAT ENERGY OF ONE POUND OF COAL

SELECTED EXAMPLES SHOWING THE AVERAGE FOR GOOD PRACTICE

With Steam Enriched Gas from Coal of 12 500 B.t.u.	Per cent
Loss in producer and auxiliaries	20.
Loss in cooling water in jackets	19.
Loss in exhaust gases	30.
Loss in engine friction	6.5
Loss in generator	0.5
Total losses	76.0
Converted into electrical energy	24.0

The Westinghouse Company Gas Engine Plant	Plant Per cent	Engine Per cent
Heat in coal	100.00	......
Radiation	10.00	......
Loss in ash	1.00	......
Cooling gases	4.00	......
Boiler fuel	10.00	......
New heat to engine	75.00	100.00
Loss in jackets	26.25	35.00
Exhaust and radiation	27.20	36.30
Engine friction	2.82	3.75
Plant auxiliaries	1.50	2.00
Net work	17.25	23.00

TABLE 21—Continued

Results at the United States Geological Survey Testing Station	Per cent
Losses in producer and auxiliaries	29.0
Losses due to cooling gas, and apparatus	21.6
Losses in exhaust	30.2
Losses due to friction, etc	5.7
Delivered to bus bar	13.5

Analysis of the Buckeye Engine Co.	Per cent
Losses due to producer and auxiliaries	20.0
Losses in cooling water	22.0
Losses in exhaust	32.3
Losses in friction	3.6
Losses in dynamo	1.3
Delivered at switch board, electrical energy	20.8

tribution of 66 to 67 per cent, which, by the way, is good practice, we may get 10 per cent of the total energy of the coal to the customer, but if this is applied with an efficiency of 75 per cent, the customer realizes but 7.5 per cent of the stored energy of the coal. This is good engineering practice at present, and it is safe to say that but few plants are doing as well. We may safely assume the general average as not running over 5 per cent, or in other words we actually use but 5 per cent of the energy of the coal and waste 95 per cent, and, what is more, the outlook for improvement in this direction is not encouraging. In using electricity for lighting we get less than one per cent of the heat value of the coal as useful light. Of all our coal wastes, electric lighting is the greatest.

73 I am fully aware of the possibilities claimed for the gas engine, but my experience thus far, and the practical results with which I am conversant, do not indicate an early fulfillment of the claims. From present indications, the best steam and the best gas engine plants appear to be about on a par with regard to coal economy. The producer plant and the boiler plant are practically equal so far as the first step in converting the coal into power is concerned. The average gas engine is more efficient than the average steam engine, but the best gas engines and the best steam engines are about equally efficient.

74 The city of St. Louis replaced pumping engines that were in first-class running order, with high-duty pumping engines that reduced the coal bills about 75 per cent, but this was not done to conserve

the Illinois coal fields for the next generation. It was good engineering under the load conditions of a large pumping station but in many power plants the installation of the triple or quadruple expansion engine, while saving coal, would increase the cost of the output. I mention this case in order to impress on the rising generation of engineers that interest on first cost must be given due weight in designing plants in order to insure success.

TABLE 22 EXTENT OF THE COAL FIELDS OF THE UNITED STATES ESTIMATED BY THE UNITED STATES GEOLOGICAL SURVEY

States	Square miles	States	Square miles
Montana	47,200	Alabama	8,430
Texas	41,300	Indiana	7,290
Illinois	35,600	Utah	4,580
North Dakota	35,500	Tennessee	4,400
Missouri	23,000	South Dakota	2,400
Iowa	20,000	Virginia	2,120
Kansas	20,000	Arkansas	1,730
Wyoming	19,900	Washington	1,100
West Virginia	17,000	North Carolina	800
Kentucky	16,670	Maryland	510
Indian Territory	14,850	California	280
Pennsylvania	14,680	Oregon	230
New Mexico	13,500	Georgia	170
Ohio	12,660	Idaho	140
Colorado	11,600		
Michigan	11,300	Total square miles	388,940

TABLE 23 COAL OUTPUT FOR THE UNITED STATES FOR 1905

States	Short tons	States	Short tons
Texas	1,200,684	Tennessee	5,963,396
Utah	1,332,372	Kansas	6,423,979
Michigan	1,473,211	Iowa	6,798,609
Montana	1,643,832	Kentucky	8,432,523
New Mexico	1,649,933	Colorado	8,826,429
Arkansas	1,934,673	Alabama	11,866,069
Washington	2,864,926	Indiana	11,895,252
Indian Territory	2,924,427	Ohio	25,552,950
Missouri	3,983,378	West Virginia	37,781,580
Virginia	4,275,271	Illinois	38,434,363
Maryland	5,108,539	Pennsylvania	196,073,487
Wyoming	5,602,021		

TABLE 24 COAL OUTPUT OF VARIOUS COUNTRIES FOR 1905

Countries	Short tons	Millions of tons. Estimated supply, Summersbach, 1904
New Zealand	1,722,379	....
S. A. Republics	2,968,117	....
Spain	3,530,569	....
New South Wales	6,742,186	....
India	9,202,711	....
Canada	8,775,933	....
Japan	11,120,934	....
Russia	21,294,639	40,000
Belgium	24,078,862	20,000
France	37,663,349	19,000
Austria-Hungary	45,209,933	17,000
Germany	191,576,074	415,000
Great Britain	264,464,408	193,000
United States	392,919,341	681,000

TABLE 25 CONSUMPTION OF COAL IN THE UNITED STATES

Year of census	Population	Decade	Coal Consumed	Pounds per capita per year
1820	9,638,453	1816 to 1825	331,356	6.9
1830	12,866,020	1826 to 1835	4,168,149	64.8
1840	17,069,453	1836 to 1845	23,177,637	271.6
1850	23,069,453	1846 to 1855	83,417,825	723.2
1860	31,443,321	1856 to 1865	173,795,014	1105.5
1870	38,558,371	1866 to 1875	419,425,104	2175.6
1880	50,155,783	1876 to 1885	847,760,319	3380.6
1890	62,622,250	1886 to 1895	1,586,098,641	5065.8
1900	75,568,686	1896 to 1905	2,832,599,452	7496.8

75 It will be noticed that the curve of the per capita rate takes on a very rapid rate of increase at 1860. The rate from 1870 to 1900 is approximately represented by the following formula:

$$\text{Log } C = 3.466 (\log T - 0.882)$$

in which T represents the time elapsed in years from 1800, and C represents the pounds of coal consumed per capita per year. The several values resulting from this formula are shown in Table 26.

76 Combining this formula with that previously given for the rate of increase of population, we obtain the following:

$$\left.\begin{array}{r}\text{Log of annual consumption}\\ \text{coal in millions of tons}\end{array}\right\} = 5.168 \log T - 7.673$$

77 Now *if* the rate at present indicated continues, we may estimate our annual consumption of coal roughly, as in Table 27. This total consumption of 614 900 millions of tons of coal would about exhaust the total supply of the country, at the present rate, in the next 100 years. It is not probable, however, that this rate will continue, but that the curve will reach a maximum and then slowly recede, becom-

TABLE 26 CONSUMPTION OF COAL PER CAPITA IN THE UNITED STATES WITH ESTIMATE TO 1950

Year	Per capita consumption of coal per year Pounds	Per capita rate from census reports
1870	2176	2176
1880	3457	3381
1890	5194	5066
1900	7499	7497
1910	10,400	....
1920	14,090	....
1930	18,630	....
1940	24,040	....
1950	30,550	....

TABLE 27 ESTIMATED ANNUAL CONSUMPTION OF COAL IN THE UNITED STATES

Year	Rate millions of tons per year	Total tons consumed during the decade
1900	460	4,600
1910	750	7,500
1920	1,190	11,900
1930	1,790	17,900
1940	2,620	26,200
1950	3,430	34,300
1960	5,220	52,200
1970	7,460	74,600
1980	9,240	92,400
1990	12,750	127,500
2000	16,580	165,800
	Total	614,900

ing asymptotic to the time axis, when the coal is all consumed or a substitute is found, or something else happens. Prognostications based on the assumption that the population and the coal consumption curves will continue along the paths of the past 40 years must be introduced with a big If, and the if must be given due weight. The study of mathematics and the science of numbers develops a keen

sense of humor, unappreciated by the laity. The law of past increase may hold good for a short time, but it is quite certain that it cannot continue indefinitely. New conditions will obtain and new methods and materials will be introduced; alcohol manufactured from waste vegetable matter is one possible alternative. When our successors can no longer afford electric light and traction they will have to get along without it.

MINERAL RESOURCES

78 Of our mineral resources, iron stands at the head as the distinct feature in our past development along mechanical lines, notwithstanding that electricity is trying to relegate us to the "copper age." An unlimited supply of metal is not needed. We require simply sufficient metal for a working capital and to keep the stock good by supplying for wear and tear. At the present time an immense amount of iron is lying in the wrecks and scrap iron piles all over the country because it does not pay to work it over.

79 The latest estimates, based on visible supply and rate of consumption, indicate an exhaustion of the supply in about 200 years. We waste iron and steel because it is cheap, but as time goes on the waste will diminish and the use be curtailed as the law of supply and demand shall dictate. The most reliable estimate that I have been able to find, places the world's production of pig iron for 1907 at about 61 000 000 tons, of which the United States furnishes about 26 000 000. In 1872 the output of the United States was about 2 000 000 tons. These amounts give us a per capita rate of about 0.05 tons in 1872 and 0.30 tons in 1907. As to the gradually increasing price of iron we quote Mr. Frank A. Munsey to the effect that the Steel Corporation contracted with the Great Northern Railroad (James J. Hill) to take ore from the Great Northern, "the price to be advanced each year over the preceding year, 3.4 cents. The price for 1897 was $0.85 per ton."

80 The conservation of iron must be by reducing waste to a minimum. As the supply of iron decreases the price will increase and the scrap iron merchant will become an important factor. The mathematical limit appears to point to the control of the old iron market as the ultimate function of the Steel Trust of the future.

81 Of the conservation of oil and natural gas we have neither time nor inclination to discuss the profligate waste in this country, particularly in the South-West where wells have been bored only to

waste the raw petroleum products and the money expended in drilling. All are familiar with the natural gas history of Pittsburg, but the waste in that case is not to be compared with that of the great South-West. The operation of natural laws in the case of these resources has rendered conservation unnecessary in many localities. The only thing that can stop this brand of insanity is a strict application to this class of natural resources of the doctrine of appropriation and beneficial use. The entire community has an interest in natural resources and should not permit waste. This doctrine is not the idle dream of the socialist but is the result of years of experience and is probably the oldest fundamental law on the statute books of the world.

Conclusion

82 Individually the members of the Society will find it necessary in the practice of the profession to design, build and operate works so as to compete with others in the same line. The crucial test will always be found in the cost per unit of output, and the real work of the engineer, in the field of conservation, will be measured by the ability of the works designed by him to compete in the markets of the world. As times and conditions change the engineer must modify his plans and processes or meet with failure. The United States at present is a country of cheap materials and high-priced labor and the result is that it pays to waste material to save labor. In countries where the reverse is found, that is, cheap labor and high-priced materials, it pays to waste labor to save materials. This fact is brought home only to the engineer who has had the opportunity to design work under foreign conditions.

83 With our present high cost of labor we must take all possible precautions to keep the price of materials low. With high-priced materials and high-priced labor we will be shut out of the world's markets. In fact, as it now stands, other countries are under-selling our mills in our own country, by virtue of low-priced skilled labor. The true exponent of the conservation movement should be the skilled labor of the United States.

84 The engineer is also interested, as one of the producing class, in the conservation of the materials of the country and likewise in the conservation of the results of his own labor. The engineering societies must fall in with the conservation idea and see to it that the returns from the societies are commensurate with the effort expended in operating them. Our societies must change with the times and

adopt new methods as the occasion requires. The American Society of Mechanical Engineers has been alive to this fact, as the journals of the year will show. The credit of the work belongs to the Secretary of the Society, Mr. Calvin W. Rice, and his efficient corps of assistants.

85 In closing I take the liberty of suggesting that the Society take one more step along the road leading to the conservation of the personal funds of its members and at the same time extending its own influence and adding to its own exchequer. This step is the production of an Engineers Notebook that will give the practicing Mechanical Engineer the fundamental constants needed for daily use and enable him to throw several yards of so-called note books from his library. Such a book, published by the Society for the use of its members, would be an incentive to engineers to join the Society and save the young members of the profession enough money to pay for life memberships.

86 I venture to suggest that most of the older members have paid out more money for note books than for dues to the Society and I most earnestly recommend that The American Society of Mechanical Engineers make an effort to conserve both the time and the funds of future members by issuing a note book which shall gradually become the standard mechanical note book, which will be a fund of information for new members, and which will make the Society known wherever engineering is practiced.

THE TRANSMISSION OF POWER BY LEATHER BELTING

CONCLUSIONS BASED PRINCIPALLY ON THE EXPERIMENTS OF LEWIS AND BANCROFT

By Carl G. Barth, Philadelphia, Pa.
Member of the Society

In his paper, Slide Rules in the Machine Shop as a Part of the Taylor System of Management, read December 1903, the writer referred to an improved theory and new formulæ developed by him for the pulling power of belting, which had been applied in connection with the slide rules described. He also stated his expectation of presenting his theory and conclusions to the Society at some future time.

2 These conclusions have since been successfully applied in practice by the extensive daily use of these slide rules in task-setting for machine operations, and the present paper was prepared with the general view of submitting this theory to the Society for the criticism and consideration of members who are interested in this subject and with the special view of supplementing Mr. Taylor's paper, On the Art of Cutting Metals. All the experimental and mathematical data for the slide rules were presented in his paper, excepting the data upon the pulling power of belting, an important element in these slide rules when applied to belt-driven machines.

3 The theory to be presented is only an additional attempt, and it is hoped a fairly successful one, to do something along lines repeatedly touched by various other investigators among the members of the Society, and the writer is glad to acknowledge his indebtedness to nearly all of these, as his work has principally consisted in taking advantage either of carefully conducted experiments recorded by them, or of suggestions of various kinds that have stimulated his interest and set him thinking.

To be presented at the Monthly Meeting (January 12, 1901) of the American Society of Mechanical Engineers. All papers are subject to revision.

4 Most notable is the paper presented by Mr. Wilfred Lewis at the Chicago meeting in 1886, in which he recorded a series of experiments conducted by himself in the spring of 1885, under the direction of Mr. J. Sellers Bancroft and at the works of William Sellers and Company, Philadelphia. In his paper was shown for the first time the fallacy of the then universal and still common assumption, that the sum of the two tensions in a belt is constant for all loads. It was also shown that the coefficient of friction between a belt and its pulley is considerably higher than was commonly assumed for ordinary working conditions, and that this coefficient varies greatly with the velocity of slip, a fact that has also been pointed out by other investigators.

5 Mr. Lewis did not, however, even attempt to develop either empirical or rational mathematical formulæ to represent the facts that he established, though his experiments, as will subsequently appear, contained all that was necessary for a complete mathematical exposition of the subject.

6 An attempt at an empirical mathematical exposition of the relations between the two tensions in a belt in accordance with the facts established in Mr. Lewis' paper, was later made by Prof. Wm. S. Aldrich in a paper read at the New York meeting in 1898. Mr. Aldrich made an original layout of a great number of Mr. Lewis' experiments in a manner that seemed to the writer to indicate an excellent way to investigate the subject, and which resulted in a discussion of Mr. Aldrich's paper, the substance of which has formed the basis for all of the writer's subsequent work on the subject.

7 But while the writer's complete theory could have been worked out without it, its practical application to the running of belt-driven machine tools could never have been made in the present satisfactory manner without the facts made known by Mr. Taylor in his paper, Notes on Belting, read at the New York meeting in 1893.

8 In this paper Mr. Taylor showed the economy of running belts under much lower tensions than those commonly used, and that the ultimate strength of a belt, or rather of the joint in a belt, does not form a proper basis for the working tension of a belt, since a belt will not long retain a tension that is even a small fraction only of its ultimate strength (see Fig. 4). However, Mr. Taylor's facts and figures were derived from comparatively slow-running belts, and he gave nothing that could be directly applied to the higher and more economical belt speeds. The modification and extension of Mr. Taylor's ideas to include high speed belts have therefore been part of the writer's personal work also.

9 To sum up, the writer's work on the subject has mainly consisted of the following:

a To establish a mathematical formula for the relation between the tension in a belt and the stretch due to this tension, based on experiments made at different times by Mr. Wilfred Lewis, Prof. W. W. Bird and himself. See Fig. 1, 2 and 3, and Par. 1–18 of the Appendix.

b By means of the knowledge of the elastic properties of leather belting expressed by this formula to develop a formula for the relations between the tensions in the two strands of a belt transmitting power, which formula takes account of the influence of the sag in a horizontal belt, and agrees substantially with the results of the experiments made by Mr. Lewis, when plotted in the manner first done by Professor Aldrich. See Fig. 6 and Par. 19–38 of the Appendix.

c To establish a formula to express the relation between the coefficient of friction between a belt and a cast iron pulley, and the velocity with which the belt slips or slides over the pulley, as revealed by plotting the results likewise obtained by Mr. Lewis. See Fig. 7, and Par. 48 of the Appendix.

d The construction of a diagram embodying the formula expressing the relation between the two tensions in a belt, the well known formula for the loss in effective tension due to centrifugal force, and the likewise well known formula for the ratio between the effective parts of the two tensions, as determined by the coefficient of friction and the arc of contact of the belt on its pulleys. These formulæ are so correlated on the diagram that problems dealing with the contained variables may be solved graphically, while a direct algebraic solution is possible only for a vertical belt, or what is the same thing, by neglecting the effect of the sag of a horizontal belt. See Plate 1 and Par. 11–24.

e Also, by means of the better knowledge gained of the elastic properties of leather belting, to develop a formula for the creep of a belt on its pulley due to the difference in the tensions in the two strands, along the lines outlined by Professor Bird in his paper on Belt Creep, read at the Scranton meeting in 1905. See Par. 41–44 of the Appendix.

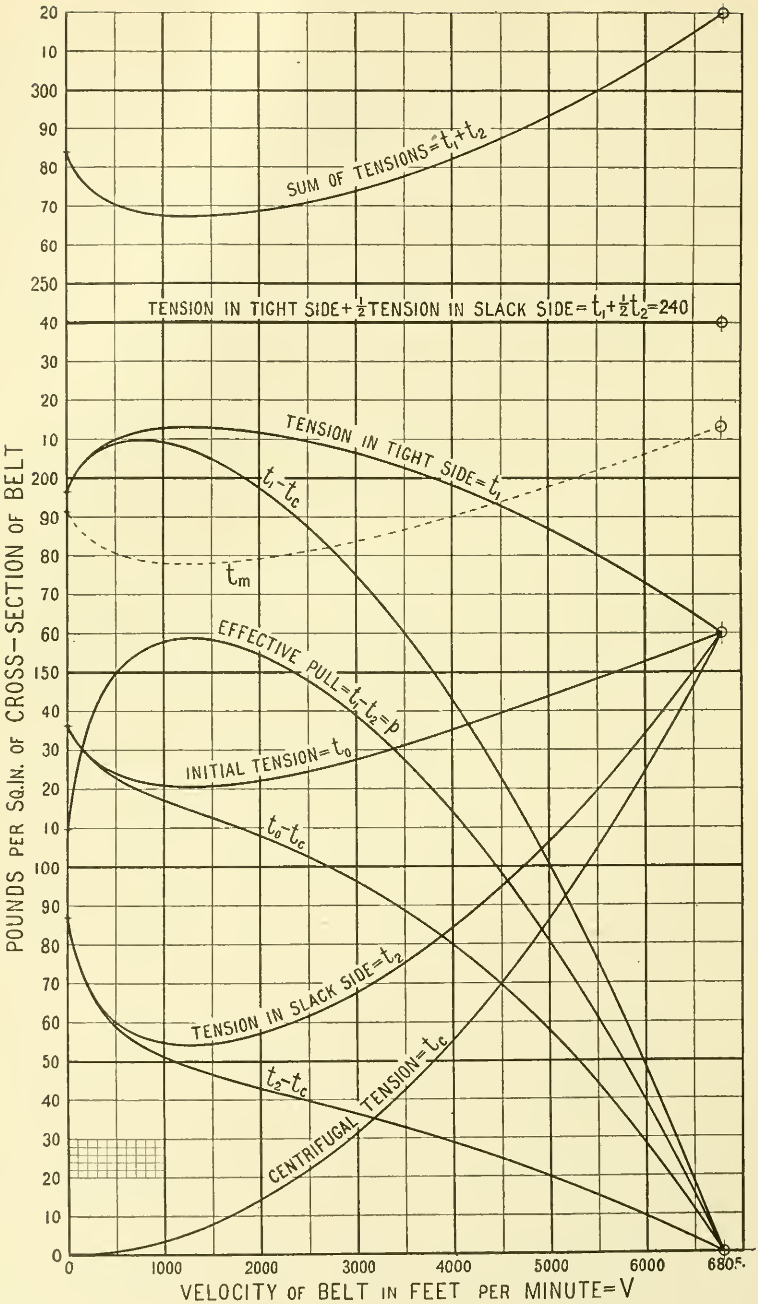


FIG. 1 DIAGRAM SHOWING THE RELATIONS OF PULLING POWER TO TENSIONS, AT ALL SPEEDS FOR A BELT OF 1 SQ. IN. SECTION

See opposite page

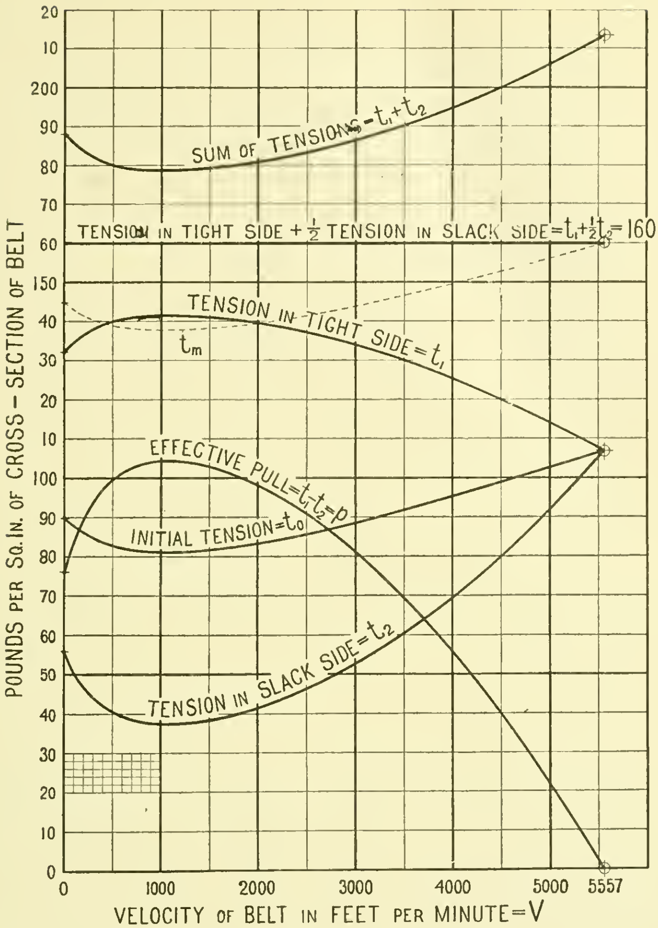


FIG. 2 DIAGRAM SHOWING THE RELATIONS OF PULLING POWER TO TENSIONS AT ALL SPEEDS FOR A BELT OF 1 SQ. IN. SECTION

Plotted with same data as Fig. 1 except that here $A = 160$ lb. for the full-drawn curves.

In Fig. 1 arc of contact = 180 deg.; coef. of friction $f = 0.5A - \dfrac{140}{500 + V}$; and the sum of tension in the tight side of belt and one-half the tension in slack side is $A = 240$ lb. for all velocities of the belt. The dotted curve marked t_m gives initial tension that with p the same as that figured from $A = 240$ corresponds to $A = 320$. This is the *maximum initial tension* to which a *machine belt* is retightened whenever the same has fallen to the *miminum initial tension* t_0.

In Fig. 2 the dotted curve t_m gives initial tension that with p the same as that figured from $A = 160$ lb. corresponds to $A = 240$ lb. This is the *maximum initial tension* to which a *countershaft belt* is retightened whenever the same has fallen to the *minimum initial tension* t_0.

f The construction of diagrams showing the pulling-power and other relations of the two tensions of a belt of 1 sq. in. cross section and 180 deg. arc of contact at different speeds, under certain conditions and assumptions recommended by the writer. See Fig. 1, 2 and 3, and Par. 38–52. Also a modification of these diagrams for extended practical use, on which may be read off: (1) The pulling power of a belt of any width and thickness and any arc of contact, between 140 and 180 deg.; (2) The initial tensions below which the belt must not be allowed to fall in order to confine the slip and the consequent loss of efficiency of transmission within certain limits; (3) The initial tension to which it is recommended that the belt be re-tightened after falling to this minimum limit. See Plate 2 and Par. 53–66.

g Finally, the construction of a slide rule serving the same purpose as the diagram just mentioned, but which is much handier than the diagram. See Fig. 5.

10 With these statements the explanation of the diagram, Plate 1, will now be taken up.

DESCRIPTION AND USE OF THE DIAGRAM PLATE 1

11 Taking the extreme left-hand bottom corner point as the origin, distances along the bottom line represent the variable tension in the tight strand or side of a belt in terms of the initial tension, while vertical distances measured to any of the bottom group of curves in the middle field of the diagram represent the corresponding tension in the slack side of the belt, also in terms of the initial tension.

12 The particular curve against which to read off a certain tension depends on the center distance of the pulleys of the belt in connection with its initial tension per square inch, and is found by consulting the small diagram directly to the right of this group of curves, in the following manner:

13 Read off the center distance c along the extreme right side of this diagram, then follow along the diagonal to the left from this reading of c until it intersects the vertical line that extends up from the reading of the initial tension t_0 on the base of the diagram.

14 From this point of intersection of c and t_0 go horizontally to the left to the reading of the corresponding value of the ratio

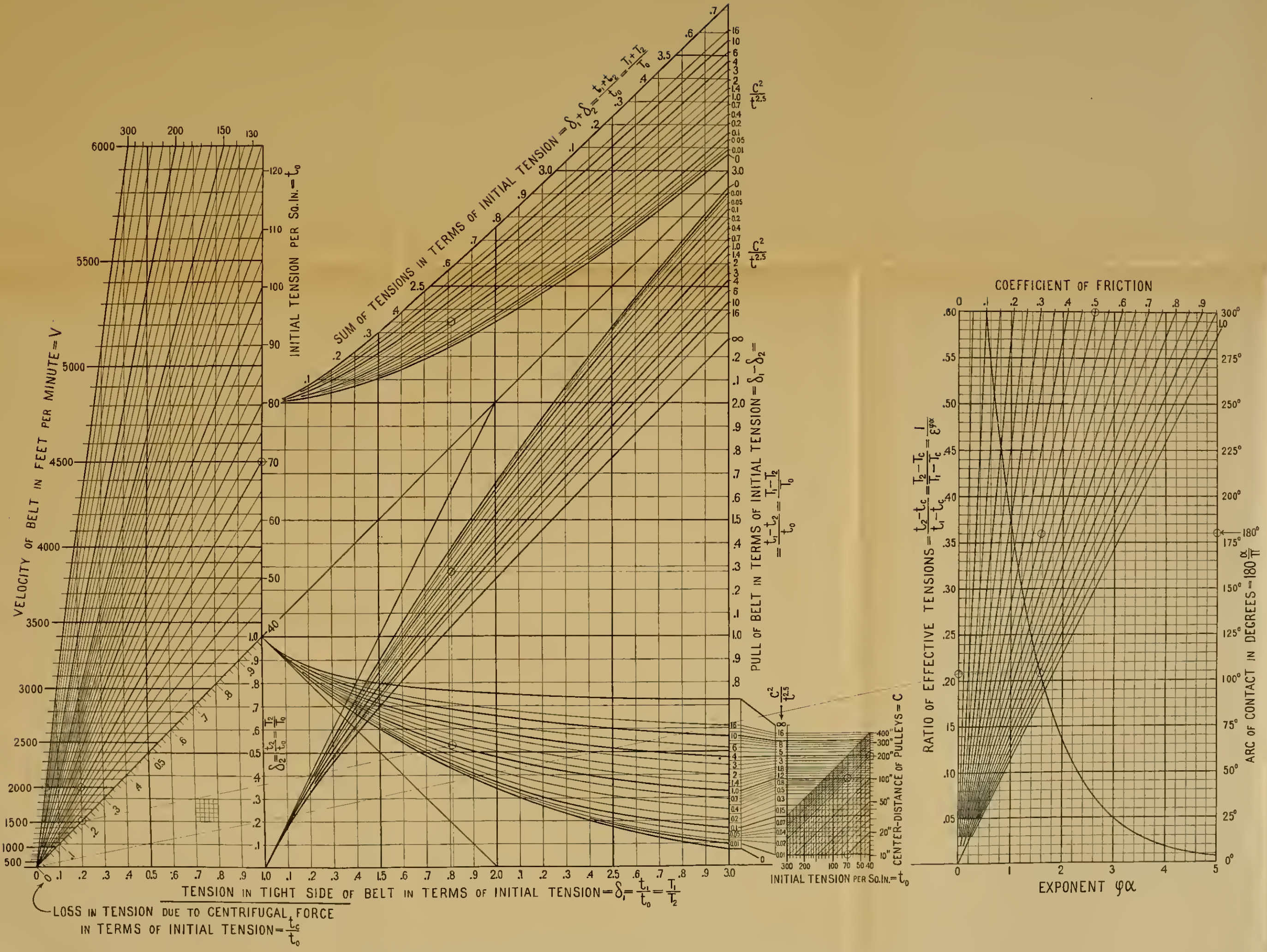


Plate 1 Diagram for the Graphical Solution of Formulae for Horizontal Belts

$\frac{c^2}{t_0^{2.5}}$ which leads directly to the proper curve in the bottom group of curves in the middle section of the diagram.

15 Against this curve there can now be read off any simultaneous tensions in the two strands of the belt corresponding to these particular values of c and t_0 of the belt under consideration.

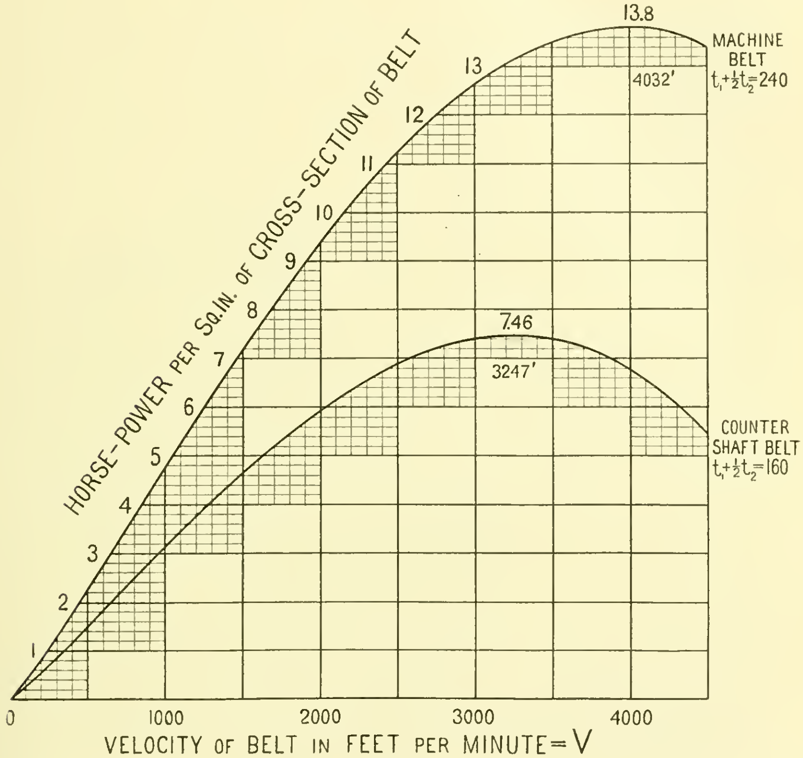
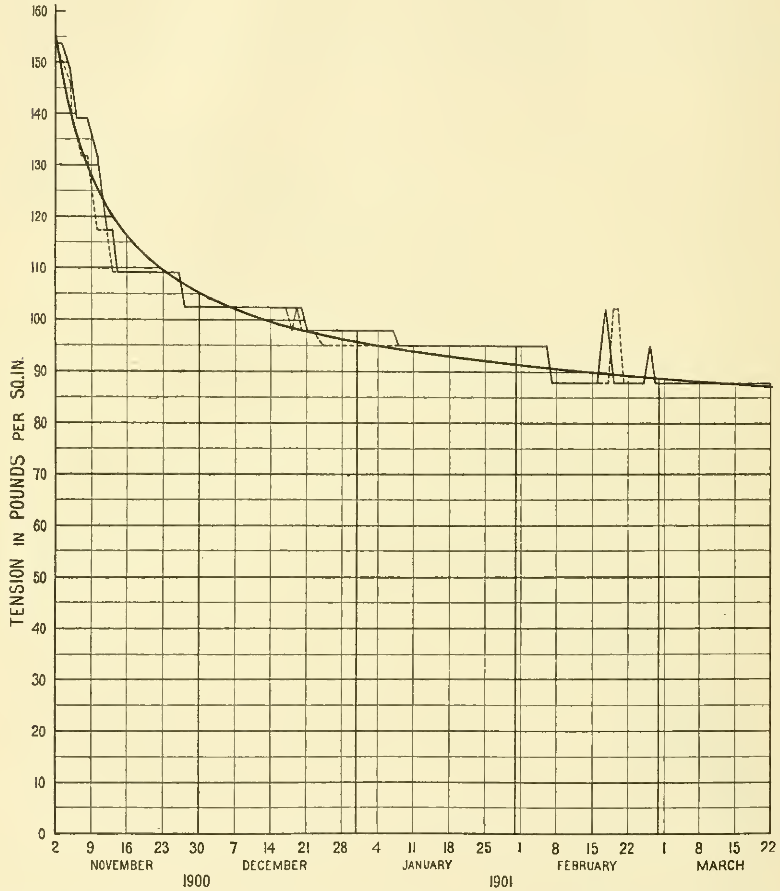


Fig. 3 Horsepower Output Corresponding to Belt Pulls in Fig. 1 and 2

16 Having noted this curve, and turning to the extreme right hand section of the diagram, the ratio of the effective tensions in the two sides of the belt corresponding to the particular coefficient of friction ϕ, and the particular arc of contact α which we wish to count on, may be determined.

17 To this end we read off the arc of contact in degrees on the extreme right-hand side of this section of the diagram, follow this

reading horizontally to the left until it intersects that line radiating from the bottom left corner of this section which is marked with the value assumed for ϕ at its termination in the extreme top line of the



EXPERIMENTS MADE ON THE FALL IN TENSION IN TWO BELTS $5\frac{3}{4}''$ WIDE BY $\frac{15}{32}''$ THICK DRIVING A LARGE ROTARY PLANER AT THE WORKS OF THE BETHLEHEM STEEL COMPANY.

The peculiarly high tensions measured on four days, during the latter part of February 1901, were probably due to something sticking in the belt scales used.

section, and then from this point of intersection go vertically up or down as the case may be, until we meet the single curve drawn in this section of the diagram. From this point in the curve we now go

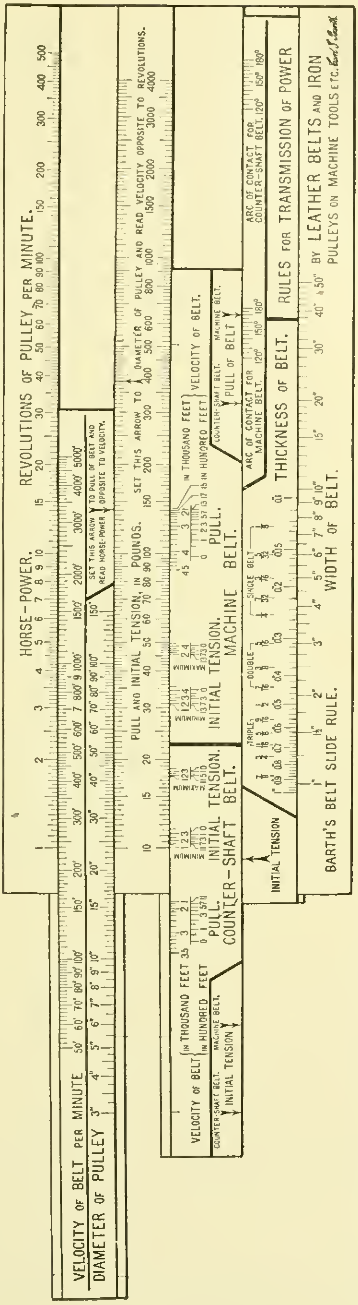


Fig. 5 Slide Rule for the More Convenient Solution of Belt Problems Solved by the Diagram, Plate 2, Based on Fig. 1 and 2

horizontally to the extreme left side of this section of the diagram and there read off the value of the ratio of the effective tensions, which is

$$\frac{t_2}{t_1} = \frac{1}{e^{\phi\alpha}}$$

for a belt running so slowly that the centrifugal force has no perceptible influence, and equal to

$$\frac{t_2 - t_c}{t_1 - t_c} = \frac{1}{e^{\phi\alpha}}$$

when the centrifugal force reduces the total tensions to the effective tensions $t_2 - t_c$ and $t_1 - t_c$ respectively.

18 From the point representing $\frac{1}{e^{\phi\alpha}}$ we now draw a line to the extreme left bottom corner point of the whole diagram.

19 Any two simultaneous coördinates to this slant line counted from its extremity in the base line of the diagram, will then also be in the ratio $\frac{1}{e^{\phi\alpha}}$

20 Passing now to the extreme slanting left side of the diagram, we read off the velocity V of the belt, follow this reading horizontally to the right until we intersect that radiating line from the extreme left bottom corner point of the diagram which is marked with the initial tension t_0 of the belt per square inch where it terminates, either in the extreme top line of this section of the diagram, or against its extreme right side.

21 From this point of intersection we now go down vertically until we reach the long 45-deg. diagonal of the diagram, on which we then read off the ratio $\frac{t_c}{t_0}$ or the loss in effective tension in terms of the initial tension, due to the centrifugal force in the belt.

22 From this point on the long 45-deg. diagonal of the diagram we now finally draw a line parallel to the line previously drawn to represent the ratio $\frac{1}{e^{\phi\alpha}}$ and extend it to intersect the curve first of all determined to represent all possible relations between the two tensions in the belt.

23 The coördinates of this point then gives the two tensions in the belt in terms of its initial tension. By extending the ordinate up to intersect that curve in the middle group of curves which is marked with the same value of $\frac{c^2}{t_0^{2.5}}$ at its terminal in the right side of this middle section of the diagram as the curve dealt with in the bottom group of curves, we read off the difference of the two tensions; that is, the effective pull of the belt, in terms of the initial tension.

24 By likewise extending the ordinate all the way up to meet that curve in the top group of curves which is marked the same as the other two curves, we may also read off the sum of the two tensions, in terms of the initial tension.

25 *Example.* A belt of the pulley center-distance $c = 200$ in. and of $2\frac{1}{2}$ sq. in. cross section, has an initial tension $T_0 = 175$ lb. and runs at a velocity $V = 2000$ ft. per minute. The arc of contact of the belt on each pulley may be taken as 180 deg., and the coefficient of friction ϕ as 0.5. What will be the centrifugal tension $T_c = 2.5\ t_c$ in the belt, what the tension $T_1 = 2.5\ t_1$ in the tight side, and what the tension $T_2 = 2.5\ t_2$ in the slack side? Also what will be the effective pull $P = T_1 - T_2$ and what the sum $T_1 + T_2$ of the two tensions?

26 *Solution.* The steps have been indicated on the diagram by little circles around the points on the several scales of variables that correspond to the values of these variables in the example. Thus, in the small diagram at the bottom of the chart, between the other two diagrams, circles have been drawn around the points indicating the unit initial tension

$$t_0 = \frac{175}{2.5} = 70,$$

and the center distance 200, giving the resulting value

$$\frac{c^2}{t_0^{2.5}} = \frac{200^2}{70^{2.5}} = 1, \text{ approximately,}$$

which determines the particular curve in each of the three groups of curves in the middle section of the diagram which apply to the belt under consideration.

27 Also, in the right-hand section of the diagram circles have been drawn indicating the coefficient of friction $\phi = 0.5$, and the arc of con-

tact 180 deg., giving the resulting value of the ratio between the effective tensions $\frac{1}{e^{\phi\alpha}} = 0.208$.

28 From the point $\frac{1}{e^{\phi\alpha}} = 0.208$ has also been drawn a line to the extreme left bottom corner of the whole diagram, the ratio of any two coördinates to this line thus being 0.208 also.

29 Again, in the left-hand section of the diagram circles are drawn about points indicating a velocity $V = 2000$ ft. and the initial tension $t_0 = 70$ leading to a resultant value of

$$\frac{t_c}{t_0} = \frac{T_c}{T_0} = 0.202$$

This means that $0.202 \times 175 = 35.35$ of the total 175 lb. of initial tension in the belt, is made ineffective by the centrifugal force due to $V = 2000$ ft.

30 From the point $\frac{t_c}{t_0} = 0.202$ has also been drawn a line parallel to the line expressing the ratio

$$\frac{1}{e^{\phi\alpha}} = 0.208$$

so that the inclination of this line expresses the same ratio between the effective belt tensions; or

$$\frac{T_2 - T_c}{T_1 - T_c} = \frac{t_2 - t_c}{t_1 - t_c} = 0.208$$

31 The point of intersection of this line with the curve previously found to express all possible relations between the working tensions in the two strands, has also been encircled, and a vertical line has been drawn through this point upwards until it intersects that curve in the top group of curves which is marked $\frac{c^2}{t_0^{2.5}} = 1$, and which accordingly expresses all possible values of the sum of the two tensions in the belt under consideration.

32 The intersection of this vertical line with that curve in the middle group which is likewise marked $\frac{c^2}{t_0^{2.5}} = 1$, and which accord-

ingly expresses all possible values of the difference of the two tensions, has also been encircled.

33 Taking the readings of the point encircled in the bottom curve, we find

$$\delta_1 = \frac{T_1}{T_0} = 1.81, \text{ and } \delta_2 = \frac{T_1}{T_0} = 0.535$$

We therefore get

$$T_1 = 1.81 \times 175 = 316.75 \text{ lb. and}$$
$$T_2 = 0.535 \times 175 = 93.63 \text{ lb.}$$

34 From this we again get

$$P = T_1 - T_2 = 316.75 - 93.63 - 223.12 \text{ lb.}$$

as the effective pull of the belt. Also, $T_1 + T_2 = 316.75 + 93.63 = 410.38$ lb. as the sum of the tensions, as against $175 \times 2 = 350$ lb., the initial sum.

35 But usually we would not be interested in the separate values of the tensions, and then we would read off directly by the encircled point in the middle group of curves,

$$\frac{p}{t_0} = \frac{P}{T_0} = \frac{T_1 - T_2}{T_0} = 1.275$$

which gives $P = 1.275 \times 175 = 223.12$ lb., the same answer as above.

36 If also interested in the sum of the tensions, we would read this off directly by the point encircled in the top group of curves,

$$\frac{t_1 + t_2}{t_0} = \frac{T_1 + T_2}{T_0} = 2.345$$

which gives $T_1 + T_2 = 2.345 \times 175 = 410.38$lb., the same answer as above.

37 The solution of problems involving long horizontal belts is thus readily enough effected by means of this diagram, but a little consideration will also make it evident that the difference in results obtained by taking the length of a belt into account and by neglecting the same is but slight, except for greater lengths and lower initial tensions than are usually employed in practice. Ordinarily, therefore, we

would use merely the very bottom curves in the bottom and top groups, and the very top curve in the middle group of curves in the middle section of the diagram, which curves are all marked

$$\frac{c^2}{t_0^{2.5}} = 0$$

and thus make no difference between horizontal and vertical belts except for exceedingly long belts.

DESCRIPTION OF DIAGRAMS, FIG. 1, 2, and 3

38 We will now take up the consideration of diagrams Fig. 1, 2, and 3, whi h form the basis of the large diagram in Plate 2. These diagrams are worked out theoretically for vertical belts only, but may be applied without hesitation to horizontal belts of the lengths usually met with in practice.

39 In his paper Notes on Belting, Mr. Taylor showed, as already mentioned, the economy of running belts under much lower tensions than those commonly figured on in proportioning a belt to do a certain amount of work.

40 He also divided the belts with which he dealt into two classes: those whose dimensions he could not well increase over what he found in use, such, for instance, as the cone belts on lathes and other machines provided with a cone pulley in a limited space; and those he could readily increase by providing larger pulleys, such as the belts leading from line-shafts to the counter-shafts of machines.

41 For belts in the first class he adopted higher tensions than for those in the second class. He also devised a set of belt-clamps provided with spring balances, by means of which he could make sure that a belt was put up under a specified initial tension, and could also ascertain its fall in tension at any time desired.

42 All this seems to be the first efforts made by an engineer to pay any systematic attention to the belting in a shop, which even today is usually left entirely to the rule-of-thumb method of the machinist or millwright.

43 The reason why Mr. Taylor had adopted, and accordingly recommended, lower belt-tensions than usually counted on in proportioning a belt to do a certain amount of work, was that a belt quickly loses its tension if it exceeds a certain amount, and thus in order to maintain such a tension, approximately, requires frequent retighten-

ing, which is a source of too much expense and leads to a rapid destruction of the belt. See Fig. 4 and Par. 8.

44 Taking Mr. Taylor's data as a starting point, the writer has finally adopted the rule, as a basis for his use of belts on belt-driven machines, that for the driving belt of a machine the *minimum initial tension* must be such that when the belt is doing the maximum amount of work intended, the *sum of the tension on the tight side of the belt and one-half the tension in the slack side will equal* 240 *lb. per square inch of cross-section for all belt speeds;* and that for a belt driving a countershaft, or any other belt inconvenient to get at for retightening or more readily made of liberal dimensions, this sum will equal *160 lb.*

45 Further, the maximum initial tension, that is, the initial tension under which a belt is to be put up in the first place, and to which it is to be retightened as often as it drops to the minimum, must be such that the sum defined above is *320 lb.* for a machine belt, and *240 lb.* for a counter-shaft belt or a belt similarly circumstanced.

46 The reason for adopting a uniform sum of the tension in the tight side and one-half the tension in the slack side, as mentioned above, instead of either a uniform initial tension, or a uniform maximum tension alone, is that the aim has been to get as uniform periods as possible for the retightening of belts at all speeds.

47 But evidently, while the maximum tension in a belt must be the greatest factor in determining the rapidity with which the belt will lose its tension as a whole, the accompanying tension in the slack strand or side must also have some influence, though not proportionally to the same extent; and hence, the idea occurred to the writer of taking it into account in the manner and to the extent stated.

48 On the diagram Fig. 1, various formulae have been plotted for 240 lb. as the constant sum at all speeds of the tight tension and one-half the slack tension per square inch cross section of belt; for a coefficient of friction that varies with the velocity according to Formula 13 in the Appendix; and an arc of contact of 180 deg. The relations of the various tensions in the belt for all speeds may there be studied to great advantage. It will thus be seen that the centrifugal tension completely balances the initial tension, at a belt speed of 6805 ft. per minute.

49 On the diagram in Fig. 2 some of these formulae have likewise been plotted, with the lesser value of 160 lb. as the constant sum of the tight tension and one-half the slack tension, but for the same values of the coefficient of friction and the arc of contact. Here the

centrifugal tension balances the initial tension at the speed of 5557 ft. per minute.

50 The diagram, Fig. 1, represents the writer's practice in connection with machine belts; that in Fig. 2 his practice in connection with counter-shaft belts (see Par. 44). Both diagrams were used as the basis for the construction of Plate 2, and for the slide rule illustrated in Fig. 5.

51 In the diagram Fig. 3 are given the horse power outputs per square inch of section of belts running under the conditions imposed in the diagrams Fig. 1 and 2.

52 It will be seen that the maximum output is 13.8 h.p. per square inch of a belt under the conditions imposed in Fig. 1, and that this is for a speed of about 4000 ft. (more exactly 4032 ft.); and that for the conditions imposed in Fig. 2, the maximum horse power is 7.46 per square inch, and that this is for a speed of about 3250 ft. (more exactly 3247 ft.)

DESCRIPTION OF DIAGRAM PLATE 2

53 In the diagram, Plate 2, the data given on the diagrams, Fig. 1, 2, and 3, for a belt of one square inch of section, and an arc of contact of 180 deg., have been so modified that almost any problem relating to belting of any size and any arc of contact can be solved.

54 This will best be illustrated by the following two examples:

55 *Example 1.* The maximum cone step on the counter-shaft of a lathe is 22 in. in diameter and wide enough to carry a 3 in. double belt. The speed of the shaft is to be 300 r.p.m. Assuming the thickness of a 3 in. double belt to be $\frac{5}{16}$ in., and the arc of contact of the belt to be 170 deg.: (*a*) What pull can the belt be counted on to exert, and what horse power will it transmit with this pull? (*b*) Under what initial tension will the belt first be put up, and retightened from time to time? (*c*) And what minimum initial tension must it not be allowed to fall below to insure the above-determined pull without undue slip?

56 *Solution.* To get the answer to question (*a*), we first turn to the small bottom portion of the diagram Plate 2, and on its right hand side note the point reading 300 r.p.m. From this we pass horizontally to the left until we intersect the vertical line from the point reading 22 in. on the scale of pulley diameters at the bottom line of the diagram. From the point of intersection we follow the diagonal line upwards to the bottom line of the main portion of the diagram, and there read the velocity of the belt to be about 1700 ft. per min.

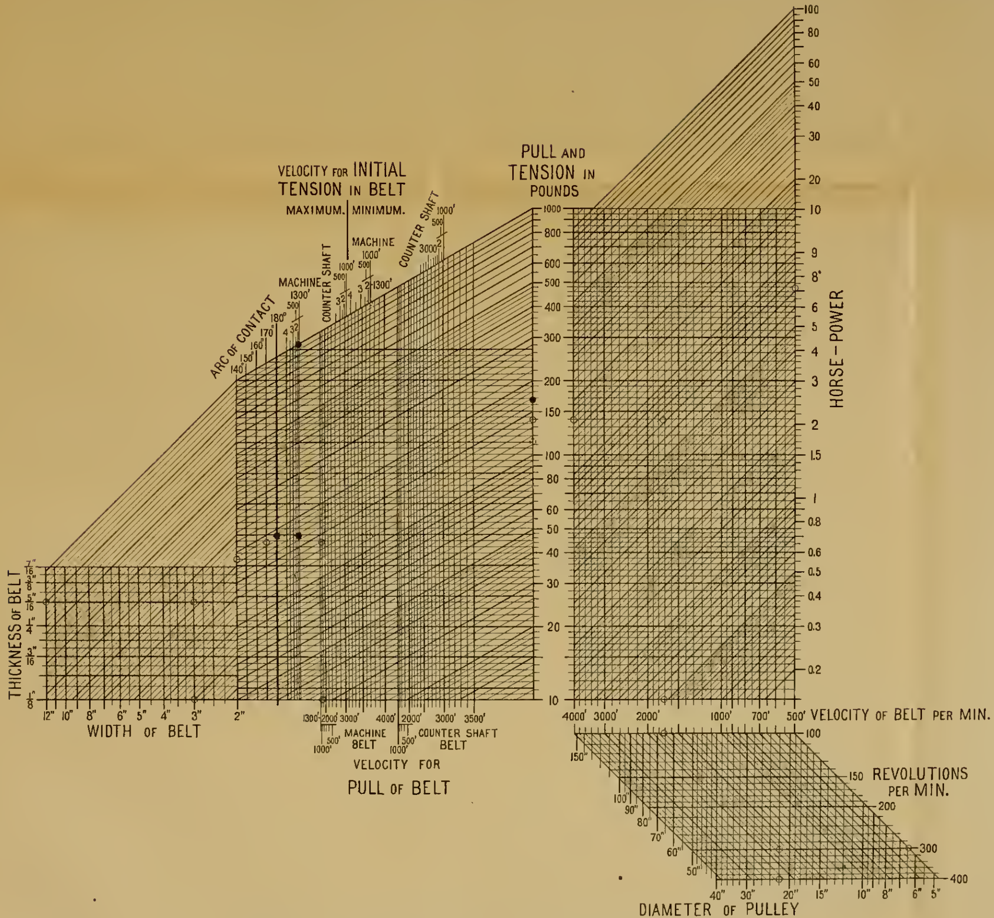


Plate 2 General Belting Diagram Incorporating the Author's Practice

57 We now note the point that corresponds to this belt speed of 1700 ft. per min. in that scale on this same bottom line of the main diagram which is marked "Velocity for Pull of Machine Belt" and interpolate a vertical line extending upwards from this point. Then leaving this for the time being, we turn to the extreme left hand portion of the diagram and there note the point corresponding to the belt thickness $\frac{5}{16}$ in. on the vertical scale to the extreme left, and also the point marked 3 in. on the scale of belt widths at the bottom of the diagram. Following these two points, respectively horizontally to the right and vertically upwards, until they intersect, we now follow the diagonal from this point of intersection until it terminates against the vertical line marked 170 deg. at the top of the diagram, in the field marked "Arc of Contact," and then continue horizontally until we intersect the interpolated vertical line for the belt speed 1700 ft. already noted.

58 From the point of intersection we follow the diagonal until we meet the vertical scale of pounds, on which we now read the belt pull to be 140 lb.; and continuing horizontally until we meet the vertical line extending upwards from the point corresponding to the belt speed originally found on the scale of belt speeds in this section of the diagram, and from this line diagonally to the vertical scale of horse power, we read off the horse power transmitted to be 7.2. All of these movements are indicated on the diagram by little circles around the various points of intersection.

59 To get the answer to question (*b*), we proceed exactly as before, with the width and thickness of the belt, except that we follow the diagonal across the portion of the diagram headed "Arc of Contact" until we meet the border line for 180 deg. From here on we proceed horizontally until we meet the vertical line that corresponds to the belt speed 1700 ft. in the field marked "Velocity for Maximum Initial Tension for Machine Belt." From the point of intersection on this vertical line we then pass diagonally to the scale of pounds, and there read the maximum initial tension to be 168 lb. Those movements for this solution on the diagram that differ from those for the answer to question (*a*), are indicated by little filled in circles around the various points of intersection noted.

60 For the answer to question (*c*), we proceed in every respect as we did for question (*b*), except that we of course proceed from the point corresponding to the belt speed 1700 ft. in that field of the scale on the top line of the diagram which is marked "Velocity for Minimum Initial Tension for Machine Belt." The answer read off on

the vertical scale of pounds is 113 lb. The movements for this solution on the diagram that differ from those for the answer to question (*b*), are indicated by little dotted circles around the points of intersection.

61 *Example 2.* The counter-shaft in Example 1 is to be driven by a belt to run at a speed of 3000 ft. per min. (*a*) What diameter of pulley is required to give this belt speed? (*b*) What pull must the belt transmit? (*c*) What width of double belt must be used? (*d*) And what will be the initial tension under which the belt must be put up, and to which it must be again retightened after falling to the minimum? (*e*) What will be its minimum tension?

62 *Solution.* (*a*) As the counter-shaft is to make 300 rev. and the belt is to run at 3000 ft. per min., we turn to the small diagram at the right hand bottom corner of the main diagram, proceed horizontally to the left from the point marked 300 on the scale of revolutions on the right, until we meet the diagonal line from the point marked 3000 on the horizontal scale of velocities. From the point of intersection we then go vertically down to the scale of pulley diameters, and there read off 38 in. as the nearest even diameter.

63 (*b*) To get the pull of the belt we remember that the cone belt was found in Example 1 to transmit 7.2 h.p. We therefore note that point on the vertical scale of horse powers at the extreme right of the main diagram which corresponds to 7.2, and then follow the diagonal from this point towards the left, until we meet the vertical line extending up from the point marked 3000 on the scale of velocities on the bottom line of this portion of the diagram. From this point of intersection we continue horizontally to the left to the vertical scale of pounds, on which we then read off the pull 80 lb.

64 (*c*) From the point corresponding to these 80 lb. we now continue diagonally to the left until we meet the vertical line extending up from the point corresponding to the belt speed 3000 on the scale marked "Velocity for Pull of Counter-Shaft Belt" at the bottom of this central portion of the main diagram. From this point we continue horizontally to the vertical line corresponding to the arc of contact, which, not being given, we will assume as 160 deg., and then again diagonally in the extreme left hand section of the diagram. Any simultaneous readings of width and thickness from points in the diagonal along which we are now moving, will then give a proper belt, and assuming as in Example 1 a thickness of $\frac{5}{16}$ in., we find the width to be $3\frac{1}{2}$ in.

65 (*d*) To find maximum initial tension for this belt, we proceed

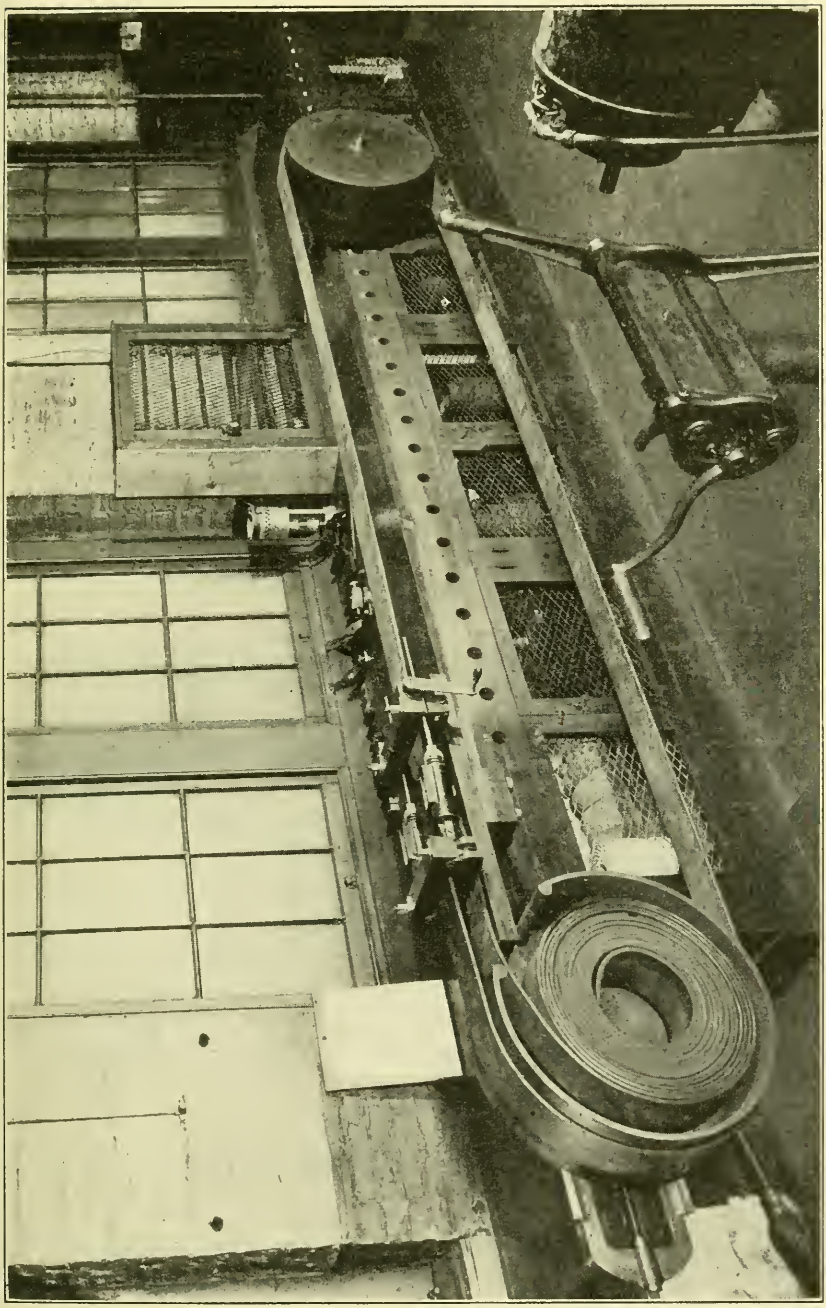


Fig. 6 Belt Bench in the Shops of the Link Belt Company, Nicetown, Philadelphia, Pa. The Use of the Belt Scales is shown in Determining the Length of a New Belt

exactly as in Example 1, except that we use the scale marked "Velocity for Maximum Initial Tension for Counter-Shaft Belt" at the top of the middle section of the diagram, and then read this off on the scale of pounds as 157 lb.

66 (*e*) Similarly, we find the minimum initial tension to be 97.5 lb.

MEANS OF SECURING AND MAINTAINING DEFINITE TENSIONS IN BELTS

67 In his paper, Notes on Belting, Mr. Taylor referred to belt-clamps provided with spring balances for weighing the tension in a belt. In the case of endless belts these scales are put directly on a belt in its final position over its pulleys, while in the case of a belt with wire lacing, this is cut to length under the required tension on the specially designed belt bench illustrated in Fig. 6. As will be seen, this bench is provided with a pair of pulleys which can be so adjusted that a tape-line will measure the same around these pulleys as over the pulleys on which the belt is to run. A belt cut and laced to give a certain tension when the bench pulleys have been properly adjusted, will then be of a length to assume the same tension over its own pulleys.

68 This indirect way of securing a desired tension in a belt was first suggested by our fellow member, Mr. Gullow Gulowsen, who also made the drawings from which the first bench and the first improved belt scale were made by the Bethlehem Steel Company in the year 1900.

APPENDIX[1]

ELASTIC PROPERTIES OF BELTING

The only experiment recorded by Mr. Lewis to establish the elastic properties of leath r belting is the following:

2 "A piece of leather belting 1 sq. in. in section and 92 in. long, was found by experiment to elongate $\frac{1}{4}$ in. when the load was increased from 100 to 150 lb., and only $\frac{1}{8}$ in. when the load was increased from 450 to 500 lb. The total elongation from 50 to 500 lb. was $1\frac{11}{16}$ in., but this would vary with the time of suspension, and the measurements here given were taken as soon as possible after applying the loads."

3 These data have been plotted in Fig. 1, in which they are remarkably well represented by the formula

$$L_t = 92\left(1 + \frac{\sqrt{t}}{830}\right)$$

in which L_t is the elongated length of the belt, and t the load or tension per square inch.

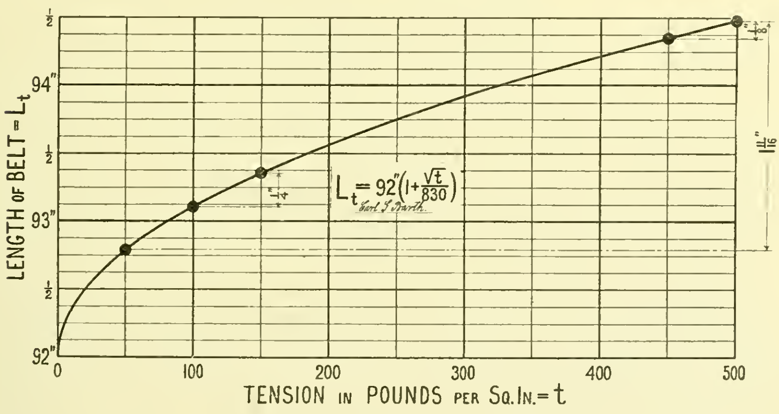


FIG. 1 PLOT OF EXPERIMENTS ON A PIECE OF BELTING 1 SQ. IN. IN SECTION AND 92 IN. LONG. TEST MADE BY WILFRED LEWIS AT THE WORKS OF WM. SELLERS & CO., PHILADELPHIA, IN 1885

[1]The full development of the mathematical formulae of this paper, with some other related matter, is given in an unpublished supplement to the Appendix, which is on file in the Library of the Society for the use of members who wish to verify the mathematical work.

4 On the strength of this formula the writer originally established the theorem that *the sum of the square roots of the tensions in a belt is constant for all loads*, when no attention is paid to the weight of the belt.

5 However, he soon realized that it would not be safe to build a theory on a single experiment of this nature; and hence, in July 1901, while in the employ of the Bethlehem Steel Company, he undertook a series of similar experiments, and obtained permission of William Sellers & Company to use their emery testing machine for that purpose with the assistance of their shop engineer, Mr. Leonard Backstrom.

6 Nine pieces of belting were tested in all. The results upon one of those pieces are shown in Fig. 2, which is typical of all of them. Similar diagrams representing the other tests are filed with the unpublished supplement to the Appendix. In all cases the tests were made as rapidly as the loads could be adjusted and the extensometer readings taken.

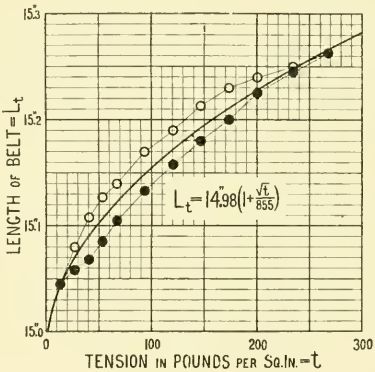


FIG. 2 PLOT OF EXPERIMENTS ON A PIECE OF SLIGHTLY USED DOUBLE BELTING $3\frac{5}{16}$ IN. WIDE BY $\frac{3}{8}$ IN. THICK

Test made by the writer at the works of Wm. Sellers & Co., Philadelphia, in 1901. The Supplement contains eight similar plots.

7 Each piece was several times subjected to a complete cycle of loads between two extremes. During the first few cycles the belts invariably showed different results, but always gave, eventually, practically the same readings for a number of cycles in succession, and these are the readings plotted in the figures.

8 The small filled-in circles represent the readings for an increasing load and the small open circles those obtained for a decreasing load. It is rather astonishing how much lag is shown by every belt. Unquestionably this has some influence on the law of change of tension in a belt, from its minimum to its maximum, along its contact with a pulley. This matter has been given some consideration in the supplement.

9 On account of this lag, apparently it would have been desirable to subject some of these belts to a series of smaller cycles, each between adjacent limits of the load. The best the writer could do with the results obtained was to average

the loop of each cycle by means of a parabolic curve, and thus obtain a value for the constant E for each belt on the supposition that the formula

$$L_t = L\left(1 + \frac{\sqrt{t}}{E}\right) \qquad [1]$$

is approximately correct. In the various formulae given, however, L is not the original 15 in. of length to which the extensometer was originally adjusted for each belt, but an ideal length only, for the estimation of the relations between the tension and the stretch for values never approaching close to zero.

10 But the best experiments for ascertaining the relations between the tension and the stretch in belts are unquestionably those by Prof. W. W. Bird, published in his paper on Belt Creep, read at the Scranton Meeting in 1905.

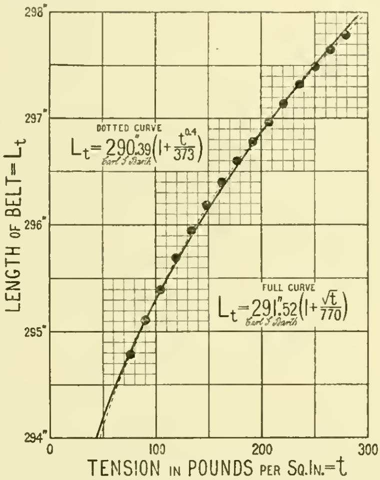


Fig. 3 Plot of Experiments on a Single 4-in., Endless, Running Belt

Test made by Prof. Wm. W. Bird at the Worcester Polytechnic Institute. The Supplement contains a similar plot on a Single 6 in. laced belt. See Professor Bird's paper on Belt Creep in Volume 26 of the Transactions for 1905.

11 These have been replotted by the writer after making some slight corrections in the lengths given by Professor Bird, by allowing for the influence of the sag in the belts, and in the tensions given, by the addition of the estimated centrifugal tension, which was not measured by Professor Bird. The centrifugal tension was estimated after obtaining from Professor Bird the information that the belts were run at a speed of about 1000 ft. per minute. One of the diagrams is shown in Fig. 3 and another has been filed with the supplement.

12 The plots made by the writer differ further from those in the original paper in that he laid off the tension in pounds per square inch of section of the belts.

13 It will be noted that the results have been approximated both by a dotted line representing a special form of the broadly general formula

$$L_t = L\left(1 + \frac{t^n}{E}\right) \qquad [2]$$

and by a full line representing this same formula with the special value $\frac{1}{2}$ for n; or in other words, formula 1. For regularity of results, these experiments are remarkable.

14 While the dotted curves with their more complicated formulae represent the experiments more closely, the full curves with their simpler formulae also cover the results so well that they may be looked upon as an excellent justification for the assumption previously made by the writer on the strength of the experiments made by Lewis and himself, namely, that *within the limits of ordinary working tensions of a belt, the difference between the lengths of a belt at different tensions is proportional to the difference between the square roots of those tensions.*

15 This proportion is implied in the general formula 1, when by L we imply, not necessarily the slack length of a belt, but an ideal slack length on the basis of which the formula gives reliable results between ordinary working limits of t.

16 Taking the average of the values of E in all twelve sets of experiments we get 895. Leaving out two experiments, one with a value of E exceeding 1000 and another for which E was less than 800, and taking the ten remaining experiments with values of E between 800 and 1000, we get 890; while if we take the average of only the two experiments by Professor Bird we get only 861.

17 As will be seen hereafter, the writer has adopted 864 as an average working value, because this figure, combined with certain other constants, results in the simple final constant coefficient 0.04 in the right member of Equation 5. For an average practical working formula on which to build an improved theory for the transmission of power by leather belting, we thus have

$$L_t = L\left(1 + \frac{\sqrt{t}}{864}\right) \qquad [3]$$

in which L_t equals the length of a belt under the unit tension t when its slack length is L.

18 However, it will appear later on, that the value 864 adopted for E has significance only in the formulae developed for long horizontal belts, as E disappears in these formulae when the weight of the belt is neglected.

LAW OF VARIATION IN THE TWO TENSIONS OF A LONG HORIZONTAL BELT

19 In developing an expression to represent the law of variation in the two tensions of a long horizontal belt, the free strands of the belt only are considered, and then, for the sake of argument, are assumed to be attached to the ends of two double levers fulcrumed in the middle, as shown in Fig. 4 and 5.

20 That the parts of the belt in contact with the two pulleys remain at practically constant length independent of any variation in the tensions of the two strands, and thus have no material influence on this variation, will be shown in the Supplement

21 In Fig. 4 the levers are parallel to each other, and the two strands of belting whose normal slack lengths l are supposed to be equal, must form equal catenaries under equal unit tensions t_0, corresponding to the equal initial tensions in the strands of a belt continuous over its two pulleys.

22 In Fig. 5 the levers have been moved through equal angles in opposite directions, thus tightening the bottom strand to the unit tension t_1, and slackening the top strand to the unit tension t_2, with corresponding changes in the respective catenaries.

23 Under this arrangement the sum of the chords of the catenaries remains constant under all variations of the tensions, a condition that corresponds to that of an actual working belt over its two pulleys, which remain at a constant distance apart under all conditions of tension in the belt

24 In considering the problem, the customary approximations in dealing with catenaries were made, in connection with Formula 1 for the elastic properties of leather belting, and then the following general formula developed for the relations between the unit working tensions t_1 and t_2 in a belt, as dependent on the initial unit tension t_0, the weight W per square inch of cross section of each free strand, and the elasticity constant E in Formula 1.

$$\sqrt{t_1} + \sqrt{t_2} = 2\sqrt{t_0} + \frac{W^2E}{24}\left(\frac{1}{t_1^2} + \frac{1}{t_2^2} - \frac{2}{t_0^2}\right) \qquad [4]$$

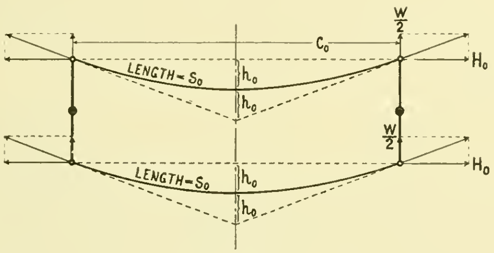


FIG. 4

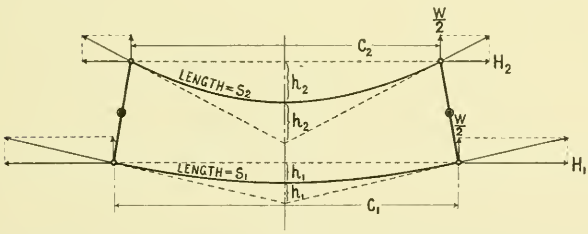


FIG. 5

Fig. 4 and 5 Representation of Change in Tensions and Sags in Strands of a Horizontal Belt

25 The average weight of a cubic inch of leather belting being about $\frac{1}{30}$ lb. we may write $W = \frac{l}{30}$, in which l is the center distance in inches between the two pulleys of a horizontal drive; and by also assuming 864 as the average value of E, as already done in Formula 3, we may write more specifically

$$\sqrt{t_1} + \sqrt{t_2} = 2\sqrt{t_0} + 0.04\, l^2\left(\frac{1}{t_1^2} + \frac{1}{t_2^2} - \frac{2}{t_0^2}\right) \qquad [5]$$

26 For very short belts the last terms in Equations 4 and 5, which are only tentatively solvable equations, become very small as compared with the term $2\sqrt{t_0}$, and by neglecting it entirely we write for vertical belts as well as for short horizontal belts, or even approximately for all belts:

$$\sqrt{t_1} + \sqrt{t_2} = 2\sqrt{t_0} \qquad [6]$$

This formula may be enunciated as a new theorem of the relations of the tension in a belt, thus: *Under any variation of the effective pull of a belt, the sum of the square roots of the tensions in the two strands remain constant,* as against the old fallacious supposition that the sum of these tensions remains constant.

27 However, without entirely neglecting the last term in Formulae 4 and 5 above, these may be made solvable with respect to t_1, by first approximating the value of this term by the substitution in it alone of an average relation of the tensions t_1 and t_2. As will appear from a study of the Diagram Plate 1 in the body of the paper, such an average relation of the tensions is

$$t_1 = \frac{t_0^2}{t_2}$$

28 Substituting this in the last term of Equation 5 and then solving this with respect to t_1 we get

$$t_1 = \left[2\sqrt{t_0} - \sqrt{t_2} + 0.04\, l^2 \left(\frac{t_2^2}{t_0^4} + \frac{1}{t_2^2} - \frac{2}{t_0^2}\right)\right]^2, \qquad [7]$$

which gives practically identical results with the original Equation 5 for such values of t_0 and l as fall within ordinary practice.

29 If we express the tensions t_1 and t_2 in terms of the initial tension t_0 by writing

$\delta_1 = \dfrac{t_1}{t_0}$ and $\delta_2 = \dfrac{t_2}{t_0}$, Formula 7 reduces to

$$\delta_1 = \left[2 - \sqrt{\delta_2} + 0.04\frac{l^2}{t_0^{2.5}}\left(\delta_2^2 + \frac{1}{\delta_2^2} - 2\right)\right]^2 \qquad [8]$$

in which form it is under certain circumstances more readily applied.

TESTING FORMULA 8 BY THE RESULTS OF LEWIS' EXPERIMENTS ON HORIZONTAL BELTS

30 In Fig. 6 the two tensions simultaneously obtained by Mr. Lewis in one series of his experiments have been plotted in terms of the initial tensions of the belt, the tensions in the tight side of the belt being laid off horizontally and the tensions in the slack side vertically, in the same manner as is done on the Diagram Plate 1, in the body of the paper. Similar diagrams, representing five additional series of experiments made by Lewis, are filed with the supplements to the Appendix.

31 However, as the apparatus used by Mr. Lewis did not measure the centrifugal tension in his belts, and as he had no occasion to calculate values of this

quantity, these have been calculated for the present purpose, and added to the effective tensions tabulated by Mr. Lewis.

32 Each experiment is represented by one of the small filled-in circles, and is numbered the same as in the tables from which the experiments were taken from Mr. Lewis' paper.

33 Unfortunately, but very naturally, the initial tension did not remain constant throughout a set of experiments, and in plotting the tensions it was therefore necessary to estimate for each individual experiment where the initial tension was between the values measured at the beginning and at the end of each set of experiments. This was done by assuming that the initial tension measured at the beginning of a set of experiments held good for the first experiment, and that the initial tension measured at the end of a set of experiments held good for the last experiment, and that there was an equal drop for each experiment.

34 That the initial tension was not constant during each set of experiments is the reason why the actual tensions obtained were not plotted, but instead their ratios δ_1 and δ_2 to their respective initial tensions.

35 In each figure, Equation 8 is also given with the center distance of the pulleys for each particular belt introduced as an approximate value of l

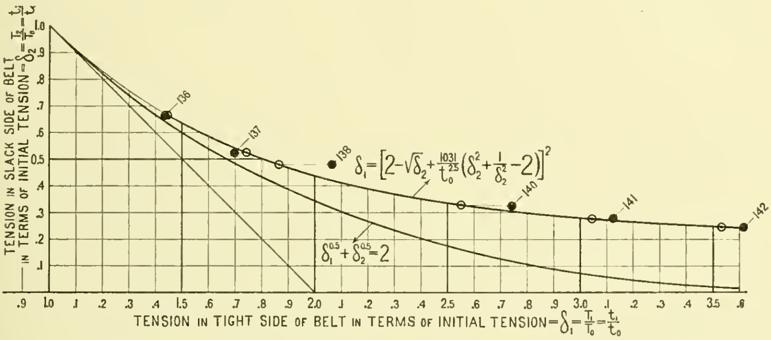


FIG. 6 PLOT OF EXPERIMENTS BY WILFRED LEWIS

Horizontal Double Belt $2\frac{1}{4}$ in. wide, $\frac{5}{16}$ in. thick and 32 ft. long. 20 in. Pulleys. Average Value of Initial Tension t_0 = 70 lb. per sq. in.

36 By the introduction of the value obtained for δ_2 in each experiment plotted, a corresponding value was calculated for δ_1 by the formula mentioned, and this value also plotted, and then a curve was drawn to cover the points thus calculated. The points themselves are indicated by the little circles drawn around them.

37 The close coincidence between the curves representing Formula 8 and the experimental results, is certainly all that can be desired in the way of an experimental verification of the soundness of Formulae 7 and 8.

38 The other, lower curve drawn on each diagram represents the relation between the tensions in a belt when the influence of its weight is neglected, as given by Equation 6, which is also given on each diagram, in the form

$$\delta_1^{0.5} + \delta_2^{0.5} = 2 \qquad [9]$$

BELT CREEP AND ITS INFLUENCE ON THE COEFFICIENT OF FRICTION BETWEEN A BELT AND ITS PULLEY

39 In the paper on his experiments, Mr. Lewis drew the conclusion that the friction between a belt and its pulley varies greatly with its velocity of slip, so that the greater the slip the greater the friction. But as he did not make a substantial study of the elastic properties of leather, upon which the phenomenon of *belt creep* depends, he had no means of distinguishing in his experiments between the necessary slip due to the creep of the belt, and the amount that was slip pure and simple of the belt as a whole.

40 In most of his experiments the belt did an amount of work that called for much greater friction between the b lt and its pulley than that corresponding to the creep of the belt alone, and this resulted in additional or true slip that produced the friction needed to make the belt exert the pull called for.

41 By means of Formula 3 it was possible also to derive a formula that gives a good idea of the actual creep of a belt in terms of the tensions in its two strands, which was the object of Professor Bird's paper on Belt Creep, from which the experiments plotted in Fig. 3 of his paper were taken.

42 This formula, the mathematical development of which is given in the Supplement, is

$$v = \frac{1}{2}(V_1 - V_2) = \frac{V_1}{2} \frac{\sqrt{t_1} - \sqrt{t_2}}{864 + \sqrt{t_1}} \qquad [10]$$

in which

v = actual average velocity of the creep of the belt on each of its two pulleys.

V_1 = velocity of the tight strand of the belt, which is the same as the circumferential velocity of the driving pulley.

V_2 = velocity of the slack strand of the belt, which is the same as the circumferential velocity of the driven pulley.

43 The total creep of the belt on both pulleys together expressed in per cent of V_1 is then

$$x = \frac{100(\sqrt{t_1} - \sqrt{t_2})}{864 + \sqrt{t_1}} \qquad [11]$$

44 It must be borne in mind, however, that Formulae 10 and 11 take account of creep only, and have nothing to do with any additional slip due to a sliding of the belt as a whole over its pulleys, though the expression

$$v = \frac{1}{2}(V_1 - V_2)$$

taken by itself always represents the total sum of the average creep of the belt and the additional sliding of the belt as a whole, over each of its pulleys, when such additional sliding does take place.

45 Considering the matter in this light Mr. Lewis calculated and tabulated the velocity of sliding from the observed loss in speed between the pulleys in his various experiments.

46 In Tables 1 and 2 appear some of the data thus tabulated by Mr. Lewis. However, instead of tabulating merely the effective tensions measured by him, the centrifugal tensions have here been figured and allowed for, and then the total

tensions thereby obtained subsequently converted into tensions per square inch of cross-section. A column has also been added giving the percentage of average slip due to belt creep alone, as figured by Formula 11.

47 It will be seen that in most of the experiments the velocity of sliding greatly exceeded the average due to the elastic creep alone, and that thus the belt as a whole slid over the pulleys in addition to the elastic creeping, thus showing that the friction corresponding to this creep alone was not enough to produce the pull the belt was called on to perform.

48 The relation between the total average velocity of sliding of the belt on each pulley, and the corresponding coefficient of friction calculated by Mr. Lewis by the formula

$$\text{Ratio of Effective Tensions} = e^{\phi\alpha}.$$

and also copied in Tables 1 and 2 of this paper, is plotted in the diagram Fig. 7 and in a similar diagram of the Supplement. On these diagrams is also shown a curve representing the equation

$$\phi = 0.6 - \frac{2}{4 + v} \qquad [12]$$

in which ϕ is the coefficient of friction and v the total average sliding velocity of the belt in feet per minute. These results were obtained from belts that had been in active service, and tested without the application of any belt dressing.

49 As a somewhat conservative average the curve is seen to cover the results obtained with the belts in a normal condition in a highly satisfactory manner.

50 The question now arises, What coefficient of friction ought to be assumed in calculating the pulling power of a belt at any given speed? In view of the foregoing it does not seem right to assume an average coefficient for all belt speeds Nor would it be right to base it on an average total sliding velocity of a belt corresponding to a fixed percentage of the belt speed, for even a very low percentage would mean a very high sliding velocity in the case of a high-speed belt, while a high percentage would mean only a moderate sliding velocity in the case of a slow-speed belt, and it would seem that the speed with which a belt slides over its pulley would principally determine the life of a belt that meets with no accident.

51 After considerable study over the subject, the writer has assumed a variable coefficient of friction expressed by the formula

$$\phi = 0.54 - \frac{140}{500 + V} \qquad [13]$$

in which V is the velocity of the belt in feet per minute.

52 Equating Formulae 12 and 13 we get

$$v = \frac{160 + 0.88\,V}{85 + 0.03\,V}$$

as the velocity of sliding on each pulley in terms of the velocity of the belt itself.

53 As the percentage of slip between the circumferential speeds of the two pulleys of a belt is twice the percentage of the average total velocity of sliding v of the belt over each pulley, we may now write

$$x = \frac{200\ v}{V} = \frac{200}{V} \cdot \frac{160 + 0.88\,V}{85 + 0.03\,V} \qquad [14]$$

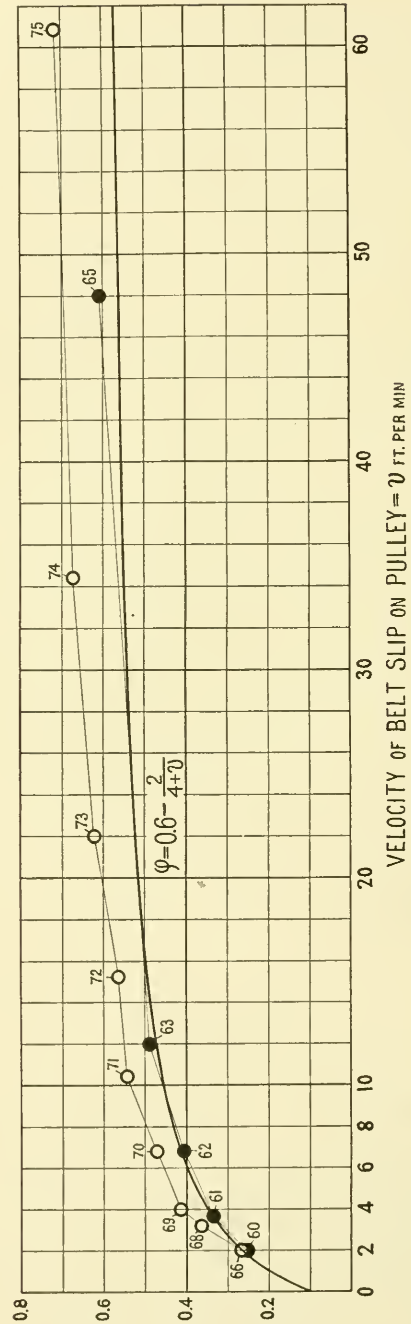


FIG. 7 PLOT OF EXPERIMENTS MADE BY MR. WILFRED LEWIS, AT THE WORKS OF WM. SELLERS & CO., PHILADELPHIA, IN 1885, ON A SINGLE BELT $5\frac{1}{2}$ IN. WIDE BY $\frac{7}{32}$ IN. THICK, BELT IN ORDINARY WORKING CONDITION

Average total initial tension in experiments 60 to 65, $= t_0 = 81.6$ lb. per sq. in.
Average total initial tension in experiments 66 to 75, $= t_0 = 127.5$ lb.

as an expression for the percentage of slip corresponding to the coefficient of friction expressed by Formula 13.

54 In Table 3 are listed simultaneous values of ϕ and x as expressed by Formulae 13 and 14 and also, for the sake of comparison, for ϕ figured by the formula

$$\phi = 0.6 - \frac{400}{800 + V},$$

which is the value of ϕ by Formula 12, for $v = \frac{V}{200}$, that is, for a uniform slip of one per cent at all belt speeds.

55 A study of Fig. 7 and the similar figure in the supplement will show that the variation in the coefficient of friction with the initial tension of the belt is so conflicting as to make it best to leave this out of consideration entirely, and so adhere to the customary assumption that the coefficient of friction is independent of the intensity of the pressure. Therefore, as our whole theory of the variation of the coefficient with the belt speed rests entirely on the formula

$$\text{Ratio of Effective Tensions} = e^{\phi\alpha}$$

this will be used unhesitatingly in spite of the fact that its absolute validity will be disputed in the Supplement for a number of reasons

EFFECT OF CENTRIFUGAL FORCE IN A BELT

56 While the effect of the centrifugal force in a fast-running belt seems to have been fully understood by all who have previously treated the subject before this Society, it is still but imperfectly understood by many engineers and mechanics; and has even been treated in a wrong way by certain text-book writers who have followed the work on belting by the late Professor Ruleaux. It has therefore seemed desirable, in the Supplement to the Appendix, to go into details on this part of the subject.

57 Subsequently, the following general formula is developed for the loss in effective tension in a belt, due to its centrifugal force:

$$t_c = \frac{w}{300\,g} V^2$$

in which

t_c = loss in effective tension per square inch of cross-section of belt.
V = velocity of belt in feet per minute.
w = weight of one cubic inch of belting in pounds.
g = acceleration of gravity in feet per second.

Substituting $w = \frac{1}{30}$, as in paragraph 25, and $g = 32\frac{1}{6}$, we have more specifically

$$t_c = 0.000003454\ V^2, \tag{15}$$

which is substantially the same formula as that given in Mr. Nagle's paper, Formula for the Horse-Power of Leather Belts, read at the Hartford meeting in 1881.

FORMULA FOR PULLING POWER OF A HORIZONTAL BELT IN TERMS OF ITS INITIAL TENSION

58 For a horizontal belt on pulleys of the center distance c and one square inch of cross-section we now have, by substituting c for l in Formula 7,

$$t_1 = \left[2\sqrt{t_0} - \sqrt{t_2} + 0.04\, c^2 \left(\frac{t_2^2}{t_0^4} + \frac{1}{t_2^2} - \frac{2}{t_0^2} \right) \right]^2 \qquad [16]$$

$$\text{Ratio of effective tensions} = \frac{t_1 - t_c}{t_2 - t_c} = e^{\phi\alpha} \qquad [17]$$

$$t_c = 0.000003454\, V^2 \qquad [15]$$

$$\phi = 0.54 - \frac{140}{500 - V} \qquad [13]$$

$$p = t_1 - t_2$$

in which formulae

c = center-distance of pulleys, in inches.

t_0 = initial tension.
t_1 = tension in tight strand or side.
t_2 = tension in slack strand or side.
t_c = centrifugal tension; or, more correctly, loss in effective tension due to centrifugal force.
p = effective pull.
} per square inch of cross-section of belt.

e = basis of Naperian System of Logarithms, 2.71828.

ϕ = coefficient of friction between belt and pulley.

α = the lesser arc of contact of belt on pulleys, in radians $= \dfrac{\pi}{180} \times$ arc in degrees.

V = velocity of belt in feet per minute.

59 However, an attempt to combine these five equations algebraically to obtain an expression of p in terms of t_0, V, and α, leads to an equation solvable by trial only, and for this reason the diagram Plate 1, the use of which was explained in Par. 11 to 24 in the body of the paper, was constructed to effect the solution graphically.

60 For the construction of this diagram Equation 5 was used after substituting c for l as above,

$$\delta_1 = \frac{t_1}{t_0}, \text{ and } \delta_2 = \frac{t_2}{t_0},$$

as in deriving Formula 8 from 7. It thus became

$$\sqrt{\delta_1} + \sqrt{\delta_2} - 2 = 0.04 \frac{c^2}{t_0^{2\cdot5}} \left(\frac{1}{\delta_1^2} + \frac{1}{\delta_2^2} - 2 \right), \qquad [18]$$

and was in that form solved tentatively to obtain a series of points in a series of curves, each representing a certain value of the factor $\frac{c^2}{t_0^{2.5}}$. On the diagram these curves form the bottom field of curves in the middle section.

61 The equation was in each case first solved to obtain an approximate value only of δ_1, in terms of an assumed value of δ_2, by resorting to the approximation δ_2^2 for $\frac{1}{\delta_1^2}$ in the right-hand member of the equation, as shown by Formula 8.

62 Then by substituting this approximate value of δ_1 in the term $\frac{1}{\delta_1^2}$ in the right-hand member of Equation 18 this was again solved for a still closer value of δ_1.

63 For the lesser values of $\frac{c^2}{t_0^{2.5}}$, this closer value of δ_1 differed inappreciably from the first approximation, while for the greatest values plotted on the diagram, the equation was solved twice to get the values actually plotted.

64 However, these greatest values of $\frac{c^2}{t_0^{2.5}}$, never occur in the practical use of belting, and hence the very construction of the diagrams under consideration proved the validity of the approximations δ_2^2 for $\frac{1}{\delta_1^2}$, which is equivalent to the approximation $\frac{t_2^2}{t_0^4}$ for $\frac{1}{t_1^2}$ resorted to in Par. 27 in modifying Equation 5 to Equation 7.

FORMULAE FOR PULLING POWER OF VERTICAL BELTS IN TERMS OF INITIAL TENSION

65 For a vertical belt the relation between the tensions of a belt is expressed by the simple Equation 6, and this can readily be combined with the rest of the equations listed in Par. 58 (in the manner done in the supplement to the Appendix), which leads to the following formula:

$$p = 4\left(\frac{e^{\phi\alpha}+1}{e^{\phi\alpha}-1} - \sqrt{\frac{4\,e^{\phi\alpha}}{(e^{\phi\alpha}-1)^2} + \frac{0.000003454\,V^2}{t_0}}\right)t_0 \qquad [19]$$

66 This formula is simple enough, though a great improvement over the one derived on the erroneous supposition that the sum of the tensions is constant for all loads.

67 By means of this formula the pulling-power of a belt can easily be determined in terms of its initial tension, however, for a uniform unit initial tension for all speeds, the unit tension in the tight side would vary so much that belts running at different speeds but tightened to a uniform maximum unit initial tension, and allowed to run until this had dropped to a uniform minimum tension, would require re-tightening at greatly different periods.

68 As already pointed out the writer has arrived at the conclusion that the periods at which belts running at different speeds will have to be re-tightened, will be nearly constant if they are all made to do their work at such initial tensions as under full load will result in the same *sum* of the *tension* in the *tight side* and

one-half the *tension* in the *slack side* of the *belt*, at the two extremes of the initial tensions, just before and after retightening.

PULLING POWER OF BELTS IN TERMS OF A CONSTANT SUM OF THE TIGHT TENSION AND ONE-HALF THE SLACK TENSION, AT ALL SPEEDS

Vertical Belts

69 This condition is expressed by the equation

$$t_1 + \tfrac{1}{2} t_2 = A = \text{a constant.}$$

Combining this with Equation 17 (in a manner shown in the Supplement) we get

$$p = \frac{(e^{\phi\alpha} - 1)(2A - 0.00001036\, V^2)}{2\, e^{\phi\alpha} + 1} \qquad [20]$$

$$t_1 = \frac{2\,A + p}{3} \qquad [21]$$

$$t_2 = \frac{2\,(A - p)}{3} \qquad [22]$$

and

$$t_0 = \frac{4\,A - p + \sqrt{(4\,A - p)^2 - 9\,p^2}}{12} \qquad [23]$$

These formulae are the ones plotted in the diagrams Fig. 1 and 2 in the body of the paper, for $A = 240$ and 160 lb., respectively.

70 By a similar treatment (as shown in the Supplement) we are also able to get an expression for the initial tension in a horizontal belt which gives results of a high degree of accuracy. This expression is

$$t_0 = \tfrac{1}{4}\left[\sqrt{t_1} + \sqrt{t_2} - \left(\frac{c}{5}\;\frac{t_1 - t_2}{t_1\,t_2}\right)^2\right]^2, \qquad [24]$$

which is evaluated by first determining p by Formula 20, and subsequently t_1 and t_2 by Formulae 21 and 22, as for a vertical belt, paragraph 69.

71 However, while this formula is of great theoretical interest, it is hardly of much practical value; as the initial tension determined by it will differ but little from that determined for a vertical belt by Formula 23, except for belts of extraordinary lengths.

72 One very interesting general conclusion may now be drawn for Formula 24; namely, that while actually doing work two horizontal belts of unequal lengths may be under precisely the same tensions, but this being the case, when idle the longer belt will be under a slightly lower initial tension.

73 It appears, however, that the popular notion that horizontal belts drive a great deal more than vertical belts, is not well founded.

TABLE 1

Experiments by Wilfred Lewis, at the Works of Wm. Sellers & Co., Philadelphia, 1885, on Single Belt 5½ in. Wide by $\frac{7}{32}$ in. Thick and in Ordinary Working Condition Without Belt Dressing. Belt Speed = 800 ft. per Minute. These Experiments are Plotted in Fig. 21, which see. See also his Paper, No. 198, Vol. 2 of Transactions, Table. 1

Experiment No.	Unit Initial Tension t_0	Unit Tension in Tight Side of Belt = t_1	Unit Tension in Slack Side of Belt = t_2	Percentage of Total Slip	Average Velocity of Sliding in feet per minute = v	Coefficient of Friction by the Formula $\frac{t_1 - t_c}{t_2 - t_c} = e^{\phi\alpha}$	Percentage of Slip due to Belt Creep alone, Formula $x = \frac{100(\sqrt{t_1} - \sqrt{t_2})}{864 + \sqrt{t_1}}$
60		125.33	58.67	0.5	2.0	0.251	0.41
61	81.6 lb.	131.42	46.58	0.9	3.6	0.336	0.53
62	per square inch	142.00	42.00	1.7	6.8	0.407	0.62
63		152.41	35.75	3.0	12.0	0.490	0.73
65		179.92	29.92	12.0	48.0	0.610	0.91
66		177.42	77.42	0.5	2.0	0.270	0.52
68		198.25	64.92	0.8	3.2	0.365	0.69
69	127.5 lb.	208.77	58.67	1.0	4.0	0.418	0.77
70	per square inch	219.08	50.75	1.7	6.8	0.472	0.87
71		229.50	46.17	2.6	10.4	0.545	0.95
72		244.08	44.08	3.8	15.2	0.569	1.02
73		256.58	39.92	3.5	22.0	0.623	1.10
74		252.42	35.75	8.6	34.4	0.677	1.13
75		283.66	33.67	15.2	60.8	0.719	1.25

TABLE 2

Experiments by Wilfred Lewis, at the Works of Wm. Sellers & Co., Philadelphia, 1885, on Double Belt 2¼ in. Wide by $\frac{5}{16}$ in, Thick and in Ordinary Working Condition Without Belt Dressing. Belt Speed 800 = ft. per Minute. These Experiments are Plotted in Fig. 22, which see. See also his Paper, No. 198, Vol. 2 of Transactions, Table 2

Experiment No.	Unit Initial Tension t_0	Unit Tension in Tight Side of Belt = t_1	Unit Tension in Slack Side of Belt = t_2	Percentage of Total Slip	Average Velocity of Sliding in feet per minute = v	Coefficient of Friction by the Formula $\frac{t_1 - t_c}{t_2 - t_c} = e^{\phi\alpha}$	Percentage of Slip due to Belt Creep alone by Formula $x = \frac{100(\sqrt{t_1} - \sqrt{t_2})}{864 + \sqrt{t_1}}$
105		104.9	47.5	0.3	1.2	0.263	0.38
106	73.5 lb.	123.4	37.5	0.8	3.2	0.395	0.57
107	per square inch	146.0	32.6	1.7	6.8	0.511	0.73
108	171.5	171.5	29.5	4.3	17.2	0.600	0.87
121		403.0	175.9	0.7	2.8	0.267	0.77
124	283.0 lb.	450.0	137.5	1.5	6.0	0.387	1.07
125	per square inch	465.0	124.8	2.3	9.2	0.424	1.17
126		482.2	113.5	3.7	14.8	0.469	1.28
127		497.5	99.2	10.1	40.4	0.523	1.39
128		511.3	227.0	0.5	2.0	0.261	0.85
131	343.5 lb.	557.0	187.2	1.1	4.4	0.350	0.99
133	per square inch	589.5	162.4	1.8	7.2	0.414	1.30
134		603.0	148.2	2.7	10.8	0.450	1.39
135		618.0	134.0	5.1	20.4	0.490	1.49

TABLE 3

Relations Between Coefficient of Friction, Velocity of Sliding and Belt Speed. See Par. 54,

V = Velocity in feet per minute	Per cent of Slip $= \frac{200}{V} \times \frac{160 + 0.88V}{85 + 0.03V}$	Velocity of Sliding $v = \frac{160 + 0.88V}{85 + 0.03V}$	Coefficient of Friction of $\phi = 0.54 - \frac{140}{500 + V}$	Velocity of Sliding at 1 per cent slip $v = \frac{V}{200}$	Coefficient of Friction of $\phi = 0.6 - \frac{2}{4 + v} = 0.6 - \frac{400}{800 + V}$
0	∞	1.88	0.260	0.00	0.100
50	9.432	2.36	0.285	0.25	0.129
100	5.636	2.82	0.307	0.50	0.156
200	3.690	3.69	0.340	1.00	0.200
300	3.010	4.51	0.365	1.50	0.236
400	2.640	5.28	0.384	2.00	0.267
500	2.400	6.00	0.400	2.50	0.292
600	2.227	6.68	0.413	3.00	0.314
700	2.090	7.32	0.423	3.50	0.333
800	1.983	7.93	0.432	4.00	0.350
900	1.889	8.50	0.440	4.50	0.365
1000	1.808	9.04	0.446	5.00	0.378
1200	1.675	10.05	0.458	6.00	0.400
1400	1.566	10.96	0.466	7.00	0.418
1600	1.474	11.79	0.473	8.00	0.433
1800	1.394	12.55	0.479	9.00	0.446
2000	1.325	13.25	0.484	10.00	0.457
2500	1.180	14.75	0.493	12.50	0.479
3000	1.067	16.00	0.500	15.00	0.495
3500	0.974	17.05	0.505	17.50	0.507
4000	0.898	17.95	0.509	20.00	0.517
4500	0.832	18.72	0.512	22.50	0.525
5000	0.768	19.40	0.514	25.00	0.531
5500	0.727	20.00	0.517	27.50	0.536
6000	0.684	20.53	0.519	30.00	0.541
6500	0.646	21.00	0.520	32.50	0.545

A NEW DEPARTURE IN FLEXIBLE STAY-BOLTS

By H. V. Wille, Philadelphia, Pa.

Member of the Society

There is practically no literature on the subject of stay-bolts, and this is particularly true of flexible stay-bolts. The increasing size and pressure of boilers make this subject of vital importance to railroads and to those responsible for the management of that type of boiler in which the firebox is stayed by a large number of bolts.

2 The boiler of the consolidation locomotive, now the prevailing type in freight service, contains about 1000 bolts less than 8 in. long and about 300 of greater length. The large types of Mallet compound locomotives now meeting with much favor have a much larger number, there being 1250 short and 300 long bolts in locomotives recently constructed.

3 In recent years some form of flexible stay-bolt, that is, one having a movable joint, has been very extensively used in the breaking zone of locomotive boilers, but their high cost and the difficulty of applying them, their rigidity from rust and scale, and the fact that their use throws an additional service on the adjacent bolts because of lost motion, has militated against their more general use.

4 It is well known that stay-bolts fail, not because of the tensional loads upon them, but from flexural stresses induced by the vibration resulting from the greater expansion of the firebox sheets than of the outside sheets, but notwithstanding the general acceptance of this theory, engineers have designed stay-bolts solely with respect to the tensional loads. It is quite general practice, it is true, to recess the bolts below the base of the thread, and this has effected a slight reduction in the fiber stress, but practically no effort has been made to design a bolt to meet the flexural stresses or even to calculate their magnitude. This is surprising in view of the simplicity of the calculations to which the ordinary formulae for flexure apply.

To be presented before The American Society of Mechanical Engineers. All papers are subject to revision.

5 Let

F = fiber stress.
E = modulus of elasticity.
I = moment of inertia.
D = diameter.
N = deflection.
L = length.
W = load.

We then have

$$W = \frac{2\ F\ I}{D\ L} \qquad (1)$$

$$N = \frac{W\ L}{3\ E\ I} \qquad (2)$$

substituting

$$N = \frac{2\ F\ L^2}{3\ E\ D} \qquad (3)$$

$$F = \frac{3\ E\ D\ N}{2\ L^2}\ * \qquad (4)$$

This formula shows that the stress increases in direct proportion to the diameter and decreases as the square of the distance between the sheets.

6 The application of the formula to service conditions gives the following stresses:

Conditions: Bolt spacing, 4 in. centers.
Assumed expansion, 4/100 in.
Length of bolt, 6 in.

Type	Diameter of Bolt	Flexural Stress
Iron	$1\frac{1}{8}$ in.	51,500
Iron	1 "	45,000
Iron	$\frac{7}{8}$ "	39,400
Spring steel	1 in. ends $\frac{7}{16}$ in. stem	19,700

7 Iron is universally employed in the manufacture of these bolts and it is not good practice to exceed a fiber stress of 12,000 lb. per

* Testing of Stay-bolt Iron, H. V. Wille, A. S. T. M., vol. 4, 1904.

square inch. It is apparent that stay-bolts in the zone which meets the expansion of the sheets are stressed above the elastic limit and must necessarily fail from fatigue. Fractures always originate at the outside sheet at the point where the bending moment due to the movement of the furnace sheets is greatest.

8 The fractures are in detail, usually starting from the base of a thread and gradually extending inward. Manufacturers of stay-bolt material have endeavored to minimize failures and to meet the unusual conditions of an iron stressed beyond its elastic limit by the supply of specially piled iron arranged with a view to breaking up the extension of the initial fracture. For this reason iron piled with

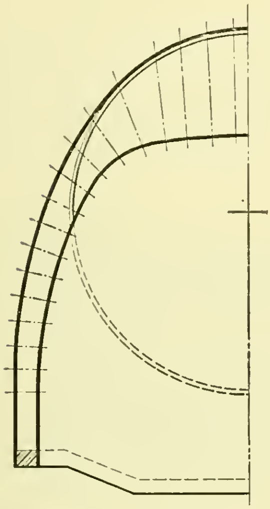


Fig. 1 Section of Firebox Showing Stay-bolts

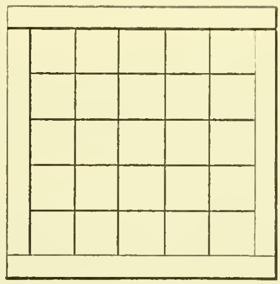


Fig. 2 Faggott Piling for Iron for Stay-bolts

a central section of small bars and an envelop of flat plates has met with much success for this class of service. In a further effort to secure an iron specially adapted to this class of work various forms of shock, vibratory and fatigue tests have been imposed. No design has yet been produced however which permits the employment of material of elastic limit sufficiently high to resist the flexural stresses, although a large class of material particularly adapted to the purpose is available.

9 It is obvious that the remedy does not lie in the use of a slow-breaking material but in the employment of material of sufficiently high elastic limit to meet the conditions of service. It is also possi-

ble to reduce the diameter of the bolt greatly by the use of such a material, thus proportionately reducing the fiber stress in flexure.

10 Stay-bolt material however must possess sufficient ductility to enable the ends to be readily hammered over to make a steam-tight joint and to afford additional security against pulling through the sheets. To meet these conditions the bolt illustrated in Fig. 3 has been designed. The stem is of the same grade of steel as that used in the manufacture of springs. It is oil-tempered and will safely stand a fiber stress of 100,000 lb. per square inch. Its high elastic limit makes it possible to reduce the diameter to $\frac{3}{8}$ or $\frac{7}{16}$ in. or even less. The ends are of soft steel, and it is thus possible to apply and head up the bolt in the usual manner.

11 The employment of a stem of the diameter indicated reduces the fiber stress in flexure to less than one-half that in the ordinary type of bolt and it is of material capable of being stressed to a high degree. It has hitherto been impossible to employ in stay-bolts any of the steels containing chromium, nickel, vanadium or other metaloid

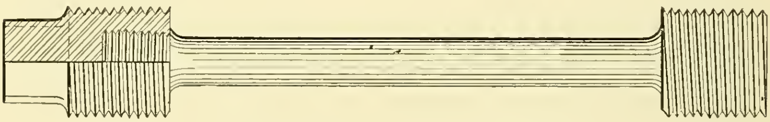


Fig. 3 Flexible Spring Steel Stay Bolt

possessing properties expecially adapted to this class of work, but these steels can readily be used in the stem of the bolt described.

12 The stem of the bolt can be flexibly secured to the end in one of the customary ways, but the flexibility of the bolt does not depend upon a flexible connection. A type of bolt with a relatively inflexible connection, usually one in which the stem screwed into the ends with a running fit, met with the most favorable consideration. Such a bolt is flexible as a spring is flexible, in that it can be deflected to meet the requirements of service without exceeding the elastic limit. In fact the stem may be of a number of pieces, either of plates or small rods, thus increasing its flexibility.

13 The actual breaking strength of the bolt sizes ordinarily employed is shown in the following statement. These bolts were recessed to the base of the thread and tested in the same form as that in which they are employed in service. For comparison the approximate weights of the usual length of bolt are also given. These

weights are for bolts over the entire length, including the squared ends for screwing the bolts into the sheets.

ACTUAL BREAKING STRENGTH OF STAY-BOLTS

Type	Nominal Diameter	Actual Breaking	Weight	Vibrations
Iron..................	1 in.	32,500	20 oz	6,000
Iron..................	$\frac{7}{8}$ "	24,500	15 "	5,200
Spring steel stem.....	1 in. ends $\frac{7}{16}$ in. stem	32,000	10 "	500,000

14 The vibrating test was made by clamping one end of the bolt in a machine and revolving the other end through a radius of $\frac{3}{32}$ in., the specimen being 6 in. long from the end of the right head to the center of the rotating head. A tensional load of 4000 lb. was also applied to the bolts. The best grades of iron bolts break on being subjected to from 5000 to 6000 rotations, whereas the spring steel bolts were

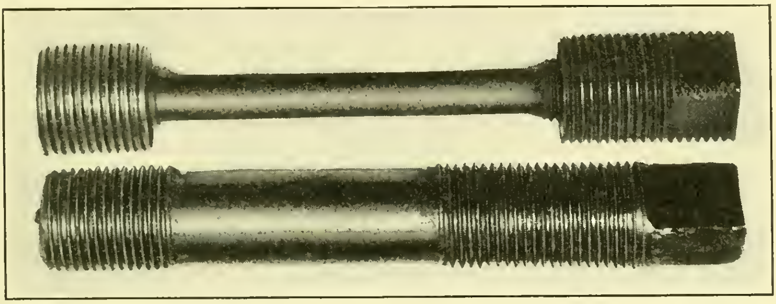


Fig. 4 Spring Flexible and Regular Iron Bolts of Same Tensile Strength.

vibrated 500,000 times without failure, and on some of them the test was continued without failure to 1,000,000 vibrations. These tests demonstrated that the bolt is not stressed beyond the elastic limit under these severe conditions and that the probability of its failure in less severe conditions is very remote.

15 The extent of the expansion which can take place in the fire-box of a boiler can readily be calculated.

Distance between stay-bolts, 4 in.
Temperature of inside sheet, 400 deg. fahr.
Temperature of outside sheet, 100 deg. fahr.
Coefficient of expansion, 0.0000066.

Then the expansion between two bolts will equal: $0.0000066 \times (400 - 100) \times 4 = 0.0079$, and each bolt will deflect 0.00395 in. It has been shown that this amount of deflection will stress the usual type of bolt beyond the elastic limit. In practice however one bolt may hold rigidly, throwing the entire deflection on the adjacent bolt, or neither bolt may deflect and the sheet will then buckle. Under this condition the neutral axis will assume the form ABC and the length AB will equal 2.00395 in. and the sheet will buckle to an extent, $BD = \sqrt{2.00395^2 - 2^2} = 0.125$ in. It is obvious that the repetition of a force sufficient to buckle a sheet $\frac{1}{8}$ in. must ultimately lead to a

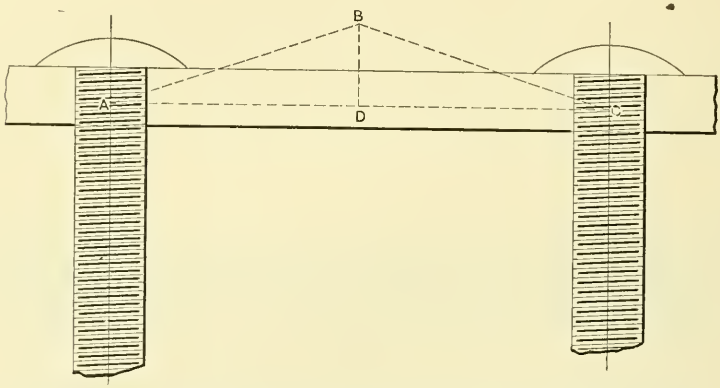


Fig. 5 Showing Manner in which Plates Buckle with Rigid Stays

crack in the furnace sheets. If, however, the bolt deflects, allowing the sheet to normally expand, the latter will be relieved of these extraneous loads.

16 A bolt of sufficient flexibility to deflect under the forces following expansion, and of material which will not be stressed beyond the elastic limit in resisting these forces, will greatly assist in reducing the cost of boiler maintenance by eliminating broken stay-bolts and reducing the stresses in the furnace plates. If in addition the bolt has a smaller diameter the life of the furnace plates should be further increased, as such a bolt will interpose less obstruction to the circulation of the water in the water legs.

DISCUSSION

THERMAL PROPERTIES OF SUPERHEATED STEAM

By Prof. R. C. H. Heck, Published in May Proceedings.

ABSTRACT OF PAPER

A graphical comparison is made of data from experiments of Knoblauch and Jakob and of Thomas upon specific heat of superheated steam under constant pressure. This shows a marked difference near the point of saturation. The author explains conditions at this point and finds evident errors in interpretation by Knoblauch and Jakob.

Views are given of the critical state of water and a new interpretation is made of Knoblauch and Jakob's results, bringing them into essential agreement with the work of Thomas. The author treats of the higher range of superheat, referring to experiments of Holborn and Henning, and gives a combination of data derived graphically showing the probable manner of variation of specific heat.

There is a table for superheated steam, giving specific heat, heat added above saturation and entropy above saturation. Other data are also referred to, with several comparisons and a statement of the general considerations involved.

DISCUSSION

The Author. The useful end finally sought in a discussion of this subject must be, not the instantaneous specific heat c_p, but the quantity of heat h needed to raise the steam from the saturation temperature to some higher temperature t. Obviously, an exact location (thermally) of the zero or starting-point of this operation is essential. This starting-point of superheat is also the terminus of another most important operation, that of evaporation. Nothing has been made clearer by recent experiment than the fact that the state of dry saturation is exceedingly elusive, and very hard to produce or to maintain in a body of steam.

2 Professor Thomas used in his calorimeter a small current of steam, broken into very thin streams where it passed over the heating surface of the wire coils. While the action observed in the superheating section of the apparatus of Knoblauch and Jakob raises serious doubts as to whether Thomas really secured homogeneous dry steam to which to add his measured superheat, nevertheless the writer is much inclined to believe that Dr. Davis has over-estimated the magnitude of the error involved. It will be noted, however, that the final curves in Fig. 6 of the paper fully embody the idea that Thomas was charging too much energy to the early part of the superheating process.

3 Even if the writer erred in following Thomas in making the curves of c_p on t sweep upward toward saturation, the amount of this error is small. As a concrete case, consider the first line of Table 1, for 1 lb. absolute pressure. In the accompanying tabulation, the first line t_s is degrees of superheat; the second is c, from the table; the third line c' is from an assumed curve which sweeps in to saturation without rise; Δh, in the fourth, is the difference in the heat h,

TABLE 1

t_s	=	0.	10.	20.0	40.0	60.0	80.0
c	=	0.513	0.475	0.465	0.457	0.454	0.453
c'	=	0.450	0.450	0.451	0.451	0.452	0.452
Δh	=	0.44	0.20	0.20	0.08	0.03	

over one interval, due to the difference between c and c'. Adding up these values of Δh, we have a total of 0.95, or say one B.t.u. If chargeable to that cause, this would represent the effect of $\frac{1}{10}$ of 1 per cent of entrained moisture. Of course there is uncertainty here, and we need more precise information; but this small possible error in the superheat measured from saturation, is certainly far less than the probable error in Regnault's value of the total heat, measured to that same "point" of saturation.

4 Knoblauch and Jakob made no attempt to go back to zero superheat experimentally. The extension of their curves to this limit is extrapolation, pure and simple, even though made with the best judgment. The writer cannot, however, accept the dictum that c_p must rise to infinity at the critical temperature, no matter what the mathematical deduction on which this idea is based. In the past much mental energy and ingenuity have been wasted in the effort to apply the general mathematical theory of thermodynamics to this

subject of superheated steam, with an entirely insufficient basis of special and exact physical knowledge; nor has any such basis been established up to this time. The relation $c_p = \infty$ belongs to the evaporation process: it means that heat can be imparted under constant pressure without raising temperature. Consideration of the writer's Fig. 3 ought to convince anyone of the impossibility of such action taking place anywhere to the right of the saturation line ECD. If the initial c_p need not thus rise to infinity at 689 deg. fahr., it is perfectly permissible to decide that Knoblauch and Jakob may have made their higher curves, which were wholly extrapolated, rise too rapidly toward saturation.

5 It is hard to see any justification for the idea that the lines of superheat h on temperature-rise t_s, which Thomas drew on his Fig. 17, can meet and start at any other point than the origin of the system of coördinates used. What Thomas did was to find, as accurately as he could, the point where any further addition of heat to steam originally slightly moist just began to raise the temperature: then from this point as zero he began to measure the superheat h. Whether he succeeded in getting precise and entirely reliable results is another matter; but curves logically representing such experiments must come to the origin. It is not well to wrench experimental results into conformity with a preconceived rigid assumption, of which the especial merit is the possibility of expressing it by a simple mathematical formula. It would be very difficult to build a physical concept about the idea of some other "origin of superheat" than the zero-point.

6 The presentation of further experimental data in regard to superheated steam will be looked for with great interest: but what we now need is a thorough review of the properties of saturated steam. At present, our knowledge of the heat required above saturation is probably more accurate than what we know about saturated steam.

THE CONVEYING OF MATERIALS

THE BELT CONVEYOR

By C. Kemble Baldwin, Published in June Proceedings

ABSTRACT OF PAPER

This paper has been presented mainly to acquaint engineers who are designing plants with the possibilities of the belt conveyor for handling heavy abrasive materials, and to give them some data which will be of service in the preparation of preliminary designs.

The author believes the following claims for this type of conveyor to be well based:

1 Large capacity with low power requirements.
2 Small maintenance charges.
3 Freedom from breakdown.
4 Light weight of mechanism for large capacities.
5 Material carried comes in contact only with the belt.
6 Perfect alignment is not absolutely necessary.
7 Can be made up into light portable sections.
8 Large overload capacity.

Local conditions have an important influence on the choice of the proper width and character of belt, general arrangement of conveyors, etc., and on these matters the specialist should be consulted.

DISCUSSION

The Author. It is to be regretted that the discussion of this subject has been contributed only by men interested in the manufacture of conveying machinery. When the paper was published the writer sent copies to a dozen large users of belt conveyors asking for comments and such power and cost data as would be of general interest. While many of these users have data which would form the most valuable part of a discussion on the conveying of materials, giving the results of actual experience unbiased by commercial considerations, it is extremely difficult to persuade a works manager to put his notes into shape for publication.

2 Mr. Willcox discusses the use of belt conveyors in salt manufacturing plants. He states that while satisfactory for handling salt from warehouse to vessels in large quantities, they are not satisfactory for handling small quantities from grainers to storage building because of the difficulty of cleaning the return belts.

3 The writer cannot agree with this because he has designed and built within the last six years several very successful plants for handling salt direct from the open pans and vacuum pans. The salt from the open pans contains about 50 per cent hot water, and the main claim for the belt conveyor is, that the salt comes in contact only with the rubber belt, which will not discolor it. There is no difficulty in cleaning the return belts by rotary brushes. After a careful investigation one of the largest salt companies in the country recently made two extensive installations of belt conveyors for handling grainer and vacuum salt. While the reciprocating conveyor described by Mr. Willcox works satisfactorily, it will be noticed that the metal scrapers work in the salt, and must in time drop pieces of rust. It is for this reason, that belt conveyors and not reciprocating conveyors were adopted by the company previously mentioned.

4 In service of this kind we find it best to paint all metal parts of the conveyor with white lead or Atcheson graphite, including the finished surfaces. Rubber belts are used throughout.

5 In the first four paragraphs of his discussion, Mr. Piez makes the following statements:

- *a* That the purpose of the original troughing idlers used with the Robins conveying belt was to *force* the belt to assume the shape of a deep continuous trough.
- *b* That to secure flexibility in the belt, strength was sacrificed.
- *c* That owing to increased loads per unit area of belt due to the deep trough, it was necessary to increase the initial tension largely.

6 From the above he draws the conclusion that, the belt being "defective in structure," the increased "unit strains" brought about a destruction of the bond between the fabric and the rubber coating, which was assisted by the lateral bending due to troughing. The remedy he states was reducing the depth of trough, thus decreasing the load per foot of belt and the unit stress in the belt.

7 The Robins Patent Belt was made with a flexible middle, part of the plies being stopped off at a varying distance from the edges. This formed a belt that would trough of its own weight and had stiff

edges which not only supported the trough between idlers, but gave the desired tensile strength. Being flexible, it was not necessary to "force" it to assume a deep trough, and having extra plies of duck at the edges its strength was not impaired in any way. That the belt is not inherently defective in design is shown by the fact that belts of this type are still running after ten years of continuous service.

8 In Par. 3 Mr. Piez states that the difference in "load per unit area" between a shallow and a deep trough causes such increased tension in the belt that it is destroyed thereby. In Par. 11 he also states that "the no-load readings are frequently from 90 to 95 per cent of the full-load readings."

9 These statements are difficult to reconcile, because if there is only 5 to 10 per cent difference between no-load and full-load, there can hardly be a heavy increase in the tractive force necessary to drive the belt on account of the slightly greater load of a deep trough, over that of a shallow trough.

10 In Par. 5 to 9 inclusive Mr. Piez states:

a That the trough of the idler was reduced because the lateral bending destroyed the belts.

b That the idlers illustrated in Fig. 6 and Fig. 7 of the writer's paper are "shallow-troughed."

c That the tendency is toward the use of an idler that is flat the greater part of its length, the end diameter being 1½ in. larger than the center diameter.

11 The first troughing idlers built by Mr. Robins some 13 years ago were of the three-pulley type illustrated in Fig. 6. The inclined pulleys were about 40 deg. from the horizontal. The angle was soon changed to 25 deg. and 30 deg., depending on the width of the belt and the duty. Mr. Piez calls them "shallow belt conveyors" and evidently agrees with the writer that they are correct. The reduction of the angle was not due to belt troubles, but to the fact that it was soon discovered that there were practical limits to the depth of load that could be put upon a belt, as has been explained by the writer under Speed and Size of Belts.

12 As the deepest practicable load could be obtained by less trough, an angle was chosen that would give: *a*, a reasonable capacity for the width of the belt; *b*, sufficient trough to support the belt between idlers, so that the minimum number of idlers would be required; *c*, enough trough to center the load properly, thus insuring a straight running belt. The angles chosen, namely 25 deg. and 30

deg., have proved so satisfactory that they have been adopted by most manufacturers.

13 The writer was not aware that there is a tendency to revert to the old type of flat belt—as practically all of the belt conveyors being installed today use idlers with pulleys inclined at 25 deg. or 30 deg. A belt supported on the idler described by Mr. Piez (lower cut Fig. 9 of Mr. Peck's paper), which is flat the greater part of its length, the edges being turned up $\frac{3}{4}$ in., has all the disadvantage of a perfectly flat belt, as a trough of $\frac{3}{4}$ in. would not materially increase its capacity over that of a flat belt. It would not in any way aid in supporting the load between idlers, thus requiring more idlers, and would have no influence on centering the load. Its place, therefore, is in the class of flat belt-conveyors which are practically of the past.

14 In Par. 10, 11 and 12, Mr. Piez states:

a That there is a slip between belt and idler pulleys of the type in Fig. 6 and Fig. 7, due to the retarding action of grease and hub friction.

b That the no-load readings are frequently 90 to 95 per cent of the full-load readings.

15 The writer, in Par. 15, calls attention to the fact that grease lubrication increases the power consumed, but gives good reasons why oil cannot be used.

16 The claim that the idler pulleys quickly become polished on the surface, due to the slip of the belt, is not the case on the conveyors designed and built by the writer. It should be kept in mind that the average belt speed is from 200 to 400 ft. per minute. Therefore the pulley speed is so slow that the weight of the belt alone will turn the pulleys without difficulty. If there is any slip it is not apparent either in the polishing of the pulleys or in damage to either belt or idlers.

17 It is surprising what a small difference there is between the no-load and the full-load readings on the belt conveyors cited by Mr. Piez. It can be explained only by a lack of proper attention to the design and workmanship of the bearings of the idlers and the proportioning of the other parts of the conveyor and its speed to the work to be done—as the writer finds from the results of hundreds of carefully tabulated tests, that the no-load readings vary from 35 to 75 per cent of the full-load readings, depending on the length and speed of the belt and the amount of material handled.

18 The power required to operate a conveyor may be divided into

that consumed by the driving mechanism and that consumed in turning over the idler pulleys. Now, the power required by the former per foot of conveyor does not of course increase proportionately with the length, while the power necessary for turning the idler pulleys varies directly with the length and load of the conveyor. We find in consequence, for short conveyors where the greater part of the power is consumed by the drive, that the difference between no-load and full-load readings is frequently small; whereas for long conveyors, in which the power required by the driving mechanism is a less important factor, the difference may amount to 50 per cent or more.

19 In Par. 62 are given certain percentages to be added to the computed horsepowers required by short conveyors, on account of the predominance of the power consumed by the driving mechanism.

20 Concerning the question of conveyor drives, Mr. Piez says, in Par. 13 to Par. 21, inclusive:

a That the writer places too little value on the use of pulleys of proper diameter.

b That each pulley around which the belt passes under full load should have a diameter of not less than 8 in. for each ply of canvas.

c That the drive shown in Fig. 10 of the writer's paper would be a destructive one to the belt.

d That the drive of a belt conveyor should be located only at the head or discharge end.

e That the multiple pulley drives described by the writer are expedients and not based on sound practice.

21 In Par. 40 the writer cautions against the use of pulleys of small diameters. Table 1 gives "minimum" size of driving pulleys and was so given under the head of drives as a guide to engineers who are designing plants, to enable them to determine clearances.

22 The writer has found it impossible to give a hard-and-fast rule for the diameters of driving pulleys. As Tables 1 and 3 show, it has been found in actual practice that the minimum diameter should be from 4 to 5 in. per ply of canvas, depending entirely on the stress in the belt and on local design conditions. Mr. Piez disregards the fact that Table 1 gives "*minimum* sizes of driving pulleys." Larger pulleys are naturally used when possible.

23 No part of the conveyor design has been given more attention than the drives and a careful tabulation of hundreds of installations

shows that the belts do not fail through separation of the plies due to pulleys of these sizes.

24 Mr. Piez's theory that the pulleys should have a diameter of 8 in. for each ply makes them unnecessarily large, causes very unsatisfactory chutes and, as pointed out in Par. 39, complicates the reduction from motor or engine.

25 Referring to the drive shown in Fig. 10, which Mr. Piez claims would destroy the belt, attention is called to the fact that while the driving pulley transmits motion to the belt, the one at the head merely acts as a bend pulley. The head pulley in such a drive may be smaller than the drive pulley.

26 The drive shown in this photograph has a 48 in. driving pulley, a 30-in. head pulley, with a 9-ply 36-in belt. The best proof that this drive is *not* a destructive one is the record of this conveyor, which has been in operation over three years and has handled over 1,500,000 tons of mine-run coal. The original belt is still in use, and to use the words of the manager of this plant, "It looks good for another million and a half tons."

27 Mr. Piez, whose business has been mainly the manufacture of chain conveyors, would locate the drive of the belt conveyor only at the head end, as would be the case with a chain conveyor. The writer has for the past five years been using the multiple-pulley drive located anywhere in the length of the conveyor, and the results have been most satisfactory. Although hundreds of them are in use, there has not been a single case where the belt separated in the plies, due to the action of the drive. In this connection, accompanying tables will be of interest, both as to the location and the style of drives in three conveying plants designed by the writer.

28 Plant *A* handles mine-run coal on the 36-in. conveyors, capacity 500 to 700 tons per hour. 30-in. conveyors handle fine coal 300 tons per hour. The conveyors have been in operation over three years and have handled over 1,500,000 tons. The original belts are still in use. Fig. 10 is a photograph of drive of Conveyor No. 2. Since these conveyors were started three years ago, every chain conveyor in the plant, except one, has been replaced by a belt conveyor.

29 Plant *B* handles mine-run and fine coal, capacity 500 to 700 tons per hour. Conveyors have been operated about three years and have handled about 1,000,000 tons.

30 Plant *C* has just been started. After making careful inspections of Plants *A* and *B* and investigating all other methods of handling coal, the owners contracted for this plant.

TABLE 1 LOCATION AND STYLE OF DRIVES, PLANT A

No.	Width Inches	Length Feet	Inclination Degrees	Location of Drive	Type of Drive
1	36	600		Head End	Multiple Pulley
2	36	300		" "	Like Fig. 10
3	36	500	Level, and 20	Center	Multiple Pulley*
4	36	50	20	Tail End	Single " †
5	36	500		" "	Multiple Pulley
6	30	200	20	Center	" "
7	30	400	20, then Level	Head End	Single "
8	30	100		Tail "	" "

* Lifts Material 90 ft.
† Driven from head of No. 3.

TABLE 2 LOCATION AND STYLE OF DRIVES, PLANT B

No.	Width Inches	Length Feet	Inclination Degrees	Location of Drive	Type of Drive
1	36	300		Head End	Multiple Pulley
2	36	775		Head "	" "
3	36	411		Head "	" "
4	36	473	20, and Level	Center	" "
5	36	673	20, and Level	Head End	" "
6	36	661		Near One End Reversible	" " Single "
7	36	82	20	Head End	
8	36	196	20	Tail "	Multiple "
9	40	100		Head "	Single "
10	36	300	20	Tail "	Multiple "
11	28	177	20	Head "	Single "
12	36	120	20	Center	Multiple "

TABLE 3 LOCATION AND STYLE OF DRIVES, PLANT C

No.	Width Inches	Length Feet	Inclination Degrees	Location of Drive	Type of Drive
1	36	75		Head End	Single Pulley
2	36	315	20	Center	Multiple "
3	36	30	20	Tail End	Single " *
4	30	32		Center	" " †
5	30	50		Head End	"
6	30	50		Head "	" "
7	30	400	20	Center	Multiple "
8	30	400	20	"	" "
9	36	640	20, and Level	"	" "
10	36	55	20	Head End	Single "
11	36	55	20	Tail "	" "
12	36	480		Center	Multiple " †
13	36	180	20, and Level	Tail End	" "

* Driven from Head of No. 2.
† Reversible Conveyor.

31 The writer believes that the foregoing is the best proof that the drive may be located at any point in the length of the conveyor, and that the multiple pulley drive, far from being an expedient, is based on sound practice and good engineering.

32 In Par. 22 to Par. 25 Mr. Piez discusses the writer's power formula and gives two examples. The results obtained from the power data presented by the writer apply to the belt conveyors manufactured by the Robins New Conveyor Company and the claim is not made that these figures will hold good on conveyors of different design.

33 In Par. 22 the writer laid stress on two fundamental points of economical conveyor design:

a The belt should run no faster than is necessary to carry the desired load. The speed may be determined from Table 2.

b The power required should always be figured for the maximum capacity at the chosen speed.

34 If these points are followed there will be a fixed relation between load and speed: therefore T in the writer's formula (load in tons per hour) is a function of both load and speed. While C is a constant for each width of conveyor, T is a variable depending on the desired load, so that if these were combined as suggested by Mr. Piez a large range of values for T would have to be used, resulting in a cumbersome table of doubtful value.

35 Mr. Peck's table of horse power, to which Mr. Piez refers, and the examples given by him in Par. 23, all indicate that they have left out of consideration the relation between speed and load.

36 Take example A, 30-in. conveyor handling coal, 253 ft. centers, capacity 215 tons per hour, speed 600 ft. per minute. Assuming coal to weigh 50 lb. per cubic foot, we find on referring to Table 2 that a 30-in. conveyor at 100 ft. will carry 145 tons of material weighing 100 lb. per cubic foot or 72½ tons of coal; to carry 215 tons therefore the speed should be about 300 ft. per minute instead of 600 ft. Naturally the lower speed will require less power and produce less wear and tear on machinery and belt. According to the writer's Formula 9, 18 h.p. will be required, but this is based on a belt-speed of 300 ft. per minute, and not 600 ft., which is bad practice.

37 Take his example B, a 30-in conveyor, 386 ft. center to center, speed 348 ft. per minute, carrying 60 tons of coke per hour. When handling such friable material as coke, the belt speed should be as low as possible to avoid breakage. The speed also should be no greater than is necessary to carry the load.

38 Taking coke at 25 lb. per cubic foot, 60 tons per hour, the capacity desired is about 4800 cu. ft. From Table 2 we find that a 30-in. conveyor has a capacity of 2900 cu. ft. at 100 ft. per minute, therefore the proper speed is about 165 ft. per minute instead of 348 ft. According to the writer's formula, this gives 4.25 h.p., 10 per cent being added for gears, and this would drive the conveyor as built by the writer. The excessive powers shown by Mr. Piez's tests are due in part to the excessive speed.

39 Mr. Messiter presents in Par. 10 of his discussion a formula in which a load factor is multiplied by the load in tons per hour and a speed factor by the speed in feet per minute. With this formula it is possible to compute the power required using a high speed and small load. Should such a conveyor at any time receive the full load at the high speed it would result in failure of belt or drive. In the writer's formula, in which the speed and load factors are combined, and where T is a function of both load and speed, this possible error is avoided.

40 Mr. Bennett, in Par. 5 of his discussion, takes exceptions to the writer's statement regarding the waterproof qualities of rubber belts. The rubber friction is applied to the duck in a plastic state. As its consistency is that of putty, it can do no more than coat the duck without reaching its inner fibers. Therefore when affected by a large quantity of water the belts are destroyed, as described by the writer in Par. 27. On the gold dredges the service is extremely severe and the belts must be built to stand excessive abrasion due to large quantities of wet rock. Therefore it is a duty which requires not only waterproof qualities, but also abrasion-resisting properties. The uncovered Balata Belt mentioned by Mr. Bennett should never have been used in this place as it was not provided with any cover to stand the wear. It should have had a heavy rubber cover.

41 Mr. Bennett states in Par. 9 that the heat of vulcanization does not affect the cotton duck of rubber belts. Actual tests, however, show that there is a loss of from 10 to 15 per cent in tensile strength due to the heat of vulcanization.

42 Mr. Messiter, in Par. 2 of his discussion, takes exceptions to the writer's formula for tension in the belt. As he states, the formula gives only the driving tension and neglects the initial tension, due to the take-ups. The substitution he proposes, while correct, is too cumbersome, and that given by the writer gives values that seem close enough for practical purposes.

43 In this connection, the writer would call attention to his

reason for presenting his paper, stated in Par. 74, "To give the engineers who were designing plants some data which will be of service in the preparation of preliminary designs." This purpose made it seem advisable to simplify and make as practical as possible all of the data presented, and to omit all unnecessary detail.

44 As this discussion has brought out some differences of opinion regarding principles and methods employed, it might be considered pertinent to add a word relative to the connection of the writer with the development of the belt conveyor industry, that members of the Society may better judge of the value of the data presented.

45 In the early days of Mr. Robins' activity he had associated with him James Barnes Humphrey, a young engineer of exceptional brilliancy, who personally designed, with no precedent to guide him, not only the various parts of the belt conveyor (many of which remain unchanged today), but also several large and difficult conveyor plants. These installations, although unique and daring in design, were so successful that the future of the belt conveyor as an industrial factor was immediately assured.

46 By his withdrawal from the work in 1900, followed shortly thereafter by his death, the industry can be said to have suffered the loss of a real genius. The writer, who was associated with Mr. Humphrey, and who carried on his pioneer work, desires that full credit be given the mind that rendered such invaluable services in the evolution of the belt conveyor.

47 The data presented represent the results of the writer's observation of thousands of conveyors, as Chief Engineer of a company manufacturing practically only belt conveyors, and all statistics and figures have been proven by actual practice.

BITUMINOUS PRODUCER PLANTS

By Elbert A. Harvey, Published in the Journal for October

ABSTRACT OF PAPER

The Industrial Gas Plant furnishes clean producer gas from bituminous coal. The plant consists of updraft producers from which the gas is made, all three principles of producer gas-making being employed; viz, semi-combustion of carbon, decomposition of steam and volatilization of hydrocarbons; coolers, in which the gas is cooled by water shower; rotary gas washers, by which the tar, dust and other impurities are beaten out of the gas; dry scrubbers, in which the gas is dried; auxiliary steam boilers and engines for operating the gas washers and furnishing steam to the producers, and tar equipment by which the tar from the gas is collected, stored and burned under the auxiliary boiler.

The gas generated by this apparatus is rich, containing all the light hydrocarbons of the coal. It averages 120 B.t.u. per cubic foot from poor coal up to 170–180 B.t.u. per cubic foot from good gas coal. The process has a net average efficiency of 75 per cent. Of the waste 25 per cent, approximately one-half, is in the form of tar which is used in carrying on the gas-making process.

The first installation of this type of apparatus was made in Indiana in 1906, a power plant of 1800 horse power in three units. Average load, 1320 b.h.p. at the switchboard, 24 hours per day, 6½ days per week. Operates on Indiana bituminous coal, consumption being 1.06 lb. per b.h.p. and 1.75 lb. per kilowatt-hour at the switchboard. Total cost for power at this plant, including coal, water, supplies, labor, and investment expenses, on the entire power plant, is .83 cents per kilowatt-hour.

A second installation of this type of apparatus is a 2000-h. p. plant installed in Indiana, furnishing gas to tempering, annealing and other small furnaces in a file works. Coal used is Indiana run of mine, and the total cost of gas, including same items as above, is 24¼ cents for the equivalent of 1000 ft. natural gas.

Another recent installation, a 750 h.p. plant operating on Ohio bituminous coal, furnishes gas for an average power load of 175-kw. with total coal consumption of 2.81 lb. per kilowatt-hour at the switchboard, and a total cost of 1.85 cents per kilowatt. The plant also furnishes gas for furnaces to the amount of the equivalent of 4000 ft. natural gas per hour, total cost being 57½ cents.

This type of plant is completely successful and can be counted on for continuous operation, 24-hour service. It generates a clean gas from bituminous coal, lignite, or other fuels high in hydrocarbon, and is suited for installations of 500 h.p. and above.

DISCUSSION

G. M. S. Tait I would like to ask Mr. Harvey a few questions as to efficiency obtained on the two-cycle engines referred to in his paper. He says they operate in the neighborhood of 10,000 B.t.u. per brake horse power. This type of engine has a great many advantages, but is not recognized as an economical engine on producer gas, and as this is the first instance of its kind in which such a high economy has been claimed on producer gas, the writer would like to know more about it.

2 I am not criticising the type of engine, but merely asking information, as it seems to me that the method of calculating heat unit consumption is subject to considerable error. For example, the author states that the gas is taken off the regular mains and that it was a fuel gas installation. How could the gas used by the engine be identified from the rest of the consumption, if a common main was used?

3 One more question is whether the history of the plant showed any trouble from premature ignitions, my experience being that this type of engine is designed to operate on a gas of very uniform composition, such as natural gas; if there is any way of operating it successfully on a gas containing a varying amount of hydrogen, this information would be of benefit to others.

John C. Parker. The speaker is sure that he is not at variance with the opinion of the members of the Society when he states that the ultimate interests of the gas producer, like those of any other article or commodity entering into commercial competition, are best conserved by recognizing its limitations, correcting them where possible, and where this can not be done, by abstaining from the attempt to enter unfavorable fields. That the gas engine cannot

compete with other forms of prime mover in certain fields is recognized, and in view of this the writer begs to present the following considerations.

2 The comparison between plants in Par. 8 of Mr. Harvey's paper is likely to be misleading if the exact local conditions are not understood. The equipment consists, for instance, of 1950 h.p. in gas engines carrying an average load of 1320 h.p. for 24 hours, which establishes a consumption of 0.95 lb. per b.h.p. per hour, whereas the steam plant carrying essentially the same average load has a consumption of 5 lb. per b.h.p. per hour. The relation between the average load carried and the plant equipment indicates a load factor very near unity for the gas engine plant. If the same conditions do not obtain for steam engine plants comparison becomes unfavorable to the latter. Assuming on the other hand that the same conditions do obtain, so large a coal consumption seems surprising. As the figures for gas producer plants are exclusive of generator steam and power for the operation of the washers it seems fair to eliminate from the charges against the steam engine plant all auxiliaries. From the size of the steam engine plant one infers that a compound condensing plant is used, and a consumption of 5 lb. per *brake* horse power per hour seems very large, even if inclusive of auxiliaries, contrary in fact to the average results obtained at St. Louis by the Geological Survey, and given in Bulletins 316 and 325. The former bulletin shows an average ratio between coal as fired per b.h.p. in the boiler and coal as fired per b.h.p. per hour in the producer, of 2.7, a maximum of 3.7, and a minimum of 1.8; with lignites and semi-bituminous coal the ratios are 2.7, 2.9, and 2.2. In view of this, one speculates as to why in the Indiana Glass Manufacturing Establishment a ratio of 5.27 should obtain.

3 Par. 9 indicates a direction in which improvement is to be expected. Contrast 1.75 lb. per kilowatt-hour at the switchboard with 1.34 lb. per kilowatt-hour at the switchboard, the difference representing the coal consumed by steaming and operating rotary washers. This excess of 30.5 per cent evidently suggests a fruitful field for development. It is to be hoped that the elimination of a necessarily inefficient type of steam engine from the washer and the application of some heat units at present wasted to the production of steam may materially reduce these losses.

4 Referring now to Par. 11 the writer would like to question the labor charges, and the advisability of operating generating plants with 12-hour shifts, especially in important industrial establishments

maintaining continuous activities. As the plant has been in operation during a period of industrial depression it is perhaps entirely possible to secure competent men at the wages mentioned. The speaker is not familiar with industrial and wage conditions in the section of the country in point, but believes that it would be impossible in the State of New York, during periods of normal business activity, to secure a head gas man at not much above 20 cents per hour, even for power gas generation, and indeed doubts whether it would be advisable even if possible. Assuredly 12 cents per hour for the producer man, 25 for the chief engine man, and 15 for the assistant engine man, are too low. In central New York we pay 20 to 25 cents per hour for the crudest kind of common labor working 8 hours daily, and appreciably larger figures than those mentioned for engine men. On comparatively small engines in our community $18 per week is an average wage for a combination engine man and stoker, and more skilled men draw more proportionately.

5 This brings up the whole question of the advisability of employing inefficient labor for this class of work. Since the coal and water bills alone come to approximately $50 daily, and the labor charge is less than one-half of this, it is obvious that the slight saving in the employment of inferior labor may readily more than compensate for itself in wastage. Gas production *is* quite technical, and the proper adjustment—or refraining from indiscriminate adjustment—of the gas engine is of extreme importance. In 1906 the U. S. Geological Survey, Bulletin 316, reporting on this very point, considered a great deal of the undeserved disrepute of gas producer plants due to the inability of the operators.

6 Par. 11 and Par. 12 contain an apparent discrepancy in the matter of first costs. Par. 11 quotes a total investment of $100 per horse power for the plant, which seems reasonable; but the drop to $55 per horse power of equipment seems almost beyond accounting for by the increased size of the plant estimated in Par. 12, although it is stated that 90 per cent of the costs involved is based on actual quotations. The writer would inquire whether these are quotations for the plant installed and whether they are firm offers. The general experience seems to be that estimated costs, based on other than firm quotations in place, are likely to be largely exceeded, and $55 per horse power seems so close as to suggest that some of the installation and housing charges have been overlooked. Surely a large part of this $55 would be covered by comparatively slow-speed electric-generating apparatus, housing and engines, to say nothing

of the producer equipment. In this connection it is interesting to note that the proportionate cost of the Garford Company plant assessed against the power equipment is only $65.52 per horse power of capacity, as against the $100 estimated against a plant of 3.6 times the size. Moreover, it is interesting to inquire whether the plant capacity in the various cases has made provision for spares and for the necessary overload capacity. The writer infers that this is not the case.

7 The tabulated data of the Hydro-Electric Power Commission of the Province of Ontario for 1906 show that the machinery cost decreased from $70 per horse power for 500-h.p. to $65 per horse power for 1000-h.p. plants; while the total cost decreased from $82 in the former to $73 in the latter case. We are evidently, in these sizes, getting to the flat part of the curve, and should not look for a material reduction of the pre-estimated cost in larger installations. Indeed these installations are much larger than the general run of plants. In fact, of the industrial establishments in the United States developing power in 1905, 108.8 was the average horse power per establishment, which, according to the Hydro-Electric Commission figures—for Canada, where the costs, it is true, might naturally be somewhat higher—gives a plant cost of about $100 per horse power as against approximately $70 estimated for steam plants.

8 As to the proper percentage to be charged on the fixed costs, it is practically impossible to borrow or to invest at less than 6 per cent per annum for interest, allowing 5 per cent actual interest and 1 per cent for the cost of floating bonds and organization. The average tax rate for 1905 on actual property valuation in cities of the United States of over 30,000 was 1.71, fixing this figure as a portion of the annual charge which must be borne by any plant. Three per cent for repairs, which is not perhaps inordinately high, together with insurance, would bring this portion of the fixed cost well above 10 per cent. While with a proper sinking fund, 5 per cent would liquidate the plant investment within the reasonable life of the plant, it seems altogether too small a sum, with the ordinary systems of finance, to cover mere physical decay beyond the range where repairs are economical, and even at that would leave nothing to provide for supervision and extraordinary emergencies. It is also to be noted that in all kinds of cases a period of construction and development of load, though less in the case of industrial enterprises than of public service utilities, must be calculated and paid for, which of necessity increases the rate of fixed charges. In view of this

it is a question whether 15 per cent per annum is very nearly adequate. The writer believes that this figure should be increased by at least 5 per cent, and possibly by more, though the exact figure is of course a matter of independent determination for each case.

9 The importance of squarely facing this element in power plant costs is illustrated by reference to any of the author's examples. Referring for instance to Par. 11, the operating charges per day are only $78.70, the fixed charges—and the writer believes these should be much increased—$90. Industrial establishments having a load factor as high as 60 per cent during a 10 or 12-hour working day are extremely rare, the maximum capacity of the plant being carried not more than 6 hours per day on the average. In such a case the fixed element in the cost would become four times as great per horse-power-hour delivered as in the instance given in the article; and as practically none of the costs other than the fuel item would be reduced, because of the necessity of maintaining a labor charge only slightly below the all-day charges if some slight loads are to be carried at night; while the efficiency of course becomes reduced, this would give a daily operating cost reduced to only $140.60 as against a power delivery at the switchboard of 5346 kw-hr. In other words the cost per kilowatt-hour increases from 0.8 to 2.63 cents.

10 As another illustration of the importance of knowing the first costs accurately and estimating the percentage fixed charge, Par. 16 and 46 may be compared. The latter paragraph shows a cost ratio for producer gas almost strictly in the ratio of the coal cost when compared with the former estimate of $24.25 per thousand feet of natural gas equivalent. As the fuel charge in the former case is but a little over one-third of the total cost, manifestly this can not be correct for identical load factors, in which case the $21.50 fuel item would be reduced to $13.45 by the reduction in cost per ton from $2.00 to $1.25. This would make a total cost of $40.50, or approximately 20.22 cents per thousand feet of natural gas equivalent. If, on the other hand, the plant were to be operated as a 24-hour plant, the investment charges would be reduced to approximately one-half, say $8.75 daily. An extra labor charge of $2.50 would presumably be required to take care of the additional night help, considering also all the possible diminution of the day help. This would make a total daily cost of $34.20, or approximately 17.1 cents per thousand feet of natural gas equivalent. It is manifest that in case of the 10-hour operation the fuel cost has influenced by only 4 cents the cost of the product rendered, whereas in the case of all-day operation the economy is as much as 7 cents.

11 These two citations perhaps serve to mark one of the serious limitations of the gas engine, and to point the force of the communication from the Chairman of the Meetings Committee with reference to the wide discrepancy in weights, and presumably in costs, between different types of engine equipments. If the gas producer plant is to meet at all the competition of steam turbine plants, which have the advantages of extremely low first cost and an excellent sustained efficiency over a wide range of load, it is essential that costs should be reduced as speedily as possible to a competitive working basis.

12 Against the excellent low load efficiency of the turbine plant is to be set the modest stand-by losses of the gas producer itself. The author quotes in the case of the Central Indiana plant a stand-by of ½ ton, against an operating consumption of 8½ tons. The ordinary steam boiler furnace is especially deficient in this respect. On the other hand it is interesting to make inquiry into the possibility of rapidly getting gas producer equipments into operation when carried, as is not uncommon in present steam practice as relays and peak plants, in conjunction with water power developments or where heat engines of some type must be used in any case to handle a widely fluctuating load.

J. R. Bibbins. The bituminous producer involves difficulties in the use of various kinds of fuel, which have only been overcome by years of experiment, and I think we have not by any means reached the ideal.

2 Considering the matter fairly, is it essential to make tar-laden gas? Are there any benefits accruing therefrom that would not be realized from a tar-free gas? I must disagree with Mr. Harvey's opinion that a more useful gas may be produced by this method than by a system which involves tar destruction in the producer.

3 There are a number of features in producer gas work which are, to my mind, essential to the ideal system:

a We must have continuous operation—24 hours a day, and 365 days a year, if desired. This has already been achieved through the use of the water seal. And it may be that future development of large power gas plants will demand a continuous system for removing ash from beneath the water seal by some form of conveyor. This is by no means an impossibility. Fuel is already handled entirely by well known mechanical means.

b The fire bed should be open and readily accessible for occasional working, and this must be capable of accomplishment at any time during operation, as otherwise 24-hour service would not be possible. This is done with the open top producer.

c The fire bed must be operated at a sufficiently low temperature to avoid the formation of clinker. This has already been accomplished and is greatly facilitated by the use of a continuous blast laden with sufficient vapor to induce the necessary endothermic reaction.

d Tar and volatiles should be completely converted into fixed gas within the producer. The difficulties and embarrassments surrounding the rapid accumulation of tar are facts which may not be treated lightly, and have undoubtedly retarded to a considerable degree the progress of bituminous work. Tar destruction is an accomplished fact.

e Auxiliary plant should be reduced to its smallest possible dimensions. This covers the incidental by-product process, auxiliary boilers, bulky power-consuming and cleaning apparatus, and large gas holders.

f A moderate heat value is desired, not excessively high, but high enough to permit obtaining a fair rating from the engine, and especially the use of high compression.

4 Here I take issue with the author's statements concerning tar-free gas. Producer practice has conformed in general to a heat value around 125 B.t.u. effective power value; but I am free to say that this standard is seldom maintained in practice, a value of 110 to 115 B.t.u. representing more nearly the actual conditions. This, however, is not so serious a matter as it seems. The decrease in engine rating for gases ranging from 125 to 110 B.t.u. is barely $\frac{1}{3}$ that from 125 to 80 B.t.u.—blast furnace gas. And in fact the loss of power with the lower producer gas could scarcely be found in the actual plant, where other matters, such as valve setting, time of ignition, temperature of intake, jacket temperature, etc., control to so much greater degree the power and efficiency of the engine. This is especially the case in very "high" gas, in which the excess heat value is largely traceable to the higher hydrocarbons. These excessively rich gases are exceedingly difficult to handle in a gas engine owing to the continual variation in their proportions, the necessity of frequent change of mixture, and their tendency to cause premature or delayed combustion.

5 In producer gas, the possibility of high compression is far more important than the addition of a few heat units to the gas. This has recently been demonstrated by some very interesting experiments by Prof. Hopkinson of Birmingham University, which clearly showed that the efficiency of a given gas engine was actually higher with a lean than with a rich gas; i. e., as the richness of the mixture increased, the efficiency decreased. This is borne out in practice by the fact that fully as high efficiencies seem to be obtainable from blast furnace gas as from natural gas with 10 to 12 times the heat value. Prof. Hopkinson attributes this to the increase in the specific heat of the products of combustion taking place at the higher temperatures. It seems true, therefore, that the excessively rich producer gas is not worth striving for, if other more important advantages are lost.

6 That the various points enumerated above are not impossibilities, is demonstrated by a bituminous producer which has been under my observation for some time. This producer has been under fire continuously for over six months without the fire being drawn. It has been run on various kinds of coal, including lignites, slack and run-of-mine, and at various rates of output, from a month's run at standby to a similar period at maximum overload. The producer has made no tar and no clinker. At all loads, and without auxiliary apparatus, it has supplied its own vapor. A gas of moderate heat value has been made sufficiently uniform to operate an engine day after day without changing the mixture or the use of a gas holder. The efficiency of the producer is reasonably good and entirely comparable with that obtainable from a producer making a tar-laden gas. Efficiency and operating runs were made through monthly periods, not for 12 or for 24 hours only. In fact, the commercial value of the gas produced has been determined by a total run of over 1000 hours by an engine under brake load test.

7 With these facts in view, I feel that the crux of the producer gas problem does not lie in the making of an exceedingly rich gas, but rather in conforming to practical standards which are at present demanded by power users and which in the end represent the ideal to which we must all conform.

8 Commenting upon the paper, Mr. Harvey encourages the inference (Par. 41) that an engine may be designed for and operated on either natural or producer gas without any interruption or adjustment. He should have qualified this statement to some degree, as it is evidently quite impossible to develop a rational and efficient

design of gas engine that permits of instant change from an excessively rich to a poor gas. Not only must the port areas be proportioned to the volumes of gas passing through them, but different-sized combustion chambers are necessary to secure the proper degree of compression for the gas to be used. And with port areas sufficiently large to accommodate both gases, it is certain that difficulties in governing would be encountered unless some adjustments were made, owing to the entirely different ranges of valve movement required.

9 In his statement of producer performance, Par. 11, Mr. Harvey submits figures which indicate a rate of combustion in the producer of 50 lb. per square foot of fuel bed per hour. Assuming four producers in operation, this would be equivalent to 25 lb. per square foot per hour. The higher rate is evidently in error: even the lower rate being extraordinarily high, and apparently almost impossible of maintenance in the service contemplated in Mr. Harvey's estimate.

10 In Par. 8 the author mentions No. 8¾ lump as designating a certain grade of Pittsburg coal. Here is an opportunity for the Society to assist in bringing about definite size standards for anthracite and bituminous coal. In my discussion of Mr. Junge's paper on low grade coals, in 1906, I attempted to show the chaotic conditions existing in the size of anthracite fuels, and no doubt bituminous sizing standards are susceptible of equal improvement.

11 In estimating fixed charges (Par. 11) I have of late come to the conclusion that straight depreciation should not be charged against a power property, but rather that depreciation be considered in the form of a sinking fund or annuity. This is simply in conformity with the actual disposition of funds in commercial accounting. Not including the factor of obsolescence, if a plant has 20 years' life, the straight depreciation is 5 per cent, but if applied in the form of a sinking fund at 5 per cent interest, the annuity is 3 per cent. The general tendency is to charge excessive rates of depreciation against power gas properties. I believe, however, that this subject should be considered more in detail and always in accord with actual accounting. The funds written off on depreciation accounts are never allowed to lie idle. They are always invested in some form, and should therefore be regarded in the nature of a sinking fund.

12 The heat value of CH_4 (Par. 15) is given at 919 B.t.u. I believe this is higher than the accepted value. It illustrates the necessity of the Society's adopting at the earliest possible moment a standard table of heat value. Recently I had occasion to compile the values from some half-dozen authoritative sources, none of

which agreed, not even the computations from the original Thomsen experiments.

13 Mr. Harvey considers frequent charging a necessity for uniform gas (Par. 20). Recent extensive experiments on this very point show the opposite results, viz: that an increase in the rate of charging of from 60 to 10-minute intervals had practically no discernible effect on the range of fluctuation in the gas. This means much less labor on the producer. The fluctuation in volatiles is, on the other hand, almost entirely due to disturbance of a partially-coked fuel bed by poking or charging, so that nothing is to be gained by more frequent agitation of the bed.

14 An important point noted in Par. 24 is the relative rate of combustion possible with very rich and very poor coals; i. e., is it possible with a fuel high in ash and low in heating value to fire at a sufficiently higher rate per square foot per hour to compensate for the lower heat value and maintain the same producer output? In other words, is it necessary to reduce producer ratings on low-grade coal?

15 It is interesting to note how nearly the figure for dust content 0.015 gr. per cubic foot, is approximated in actual practice. Tests recently made from a bituminous gas plant, which has been in operation for two years, giving good results and no trouble whatever from dirt, show 0.043 gr. at the beginning of the week and 0.15 gr. at the end. This is from six to ten times the quantity of foreign matter that Mr. Harvey mentions as a limit. I would not suggest a lower standard for impurities in gas, but it is worthy of note that the modern horizontal double-acting type of engine, such as is considered in the report of the Norton test last year, is able to operate under conditions very far from those originally stipulated. The blast furnace plant at Bessemer (near Pittsburg) actually cleans the gas to 0.02 gr. per cubic foot, yet the air at times exceeds the gas in impurities carried. Furthermore, the 500-h.p. unit originally installed at Bessemer for experimental purposes actually operated for 96 hours on crude gas direct from the furnace flues. At the end of the run, an examination of valves, cylinders, packing and pistons showed conclusively, by the absence of any scoring or sticking of parts, that the modern system of mechanical lubrication is able to cope with serious difficulties. From each valve and combustion chamber were removed about two quarts (3.62 lb.) of solid matter, consisting of dust, cinder, coke and limestone, varying in size from dust to $\frac{1}{4}$ in. or more. The problem of cleaning is important, yet the fact remains that many plants are

operating satisfactorily today on gas containing far greater impurities than expected.

THE AUTHOR Mr. Tait asks for further information in reference to the efficiency of a two-cycle engine. His question refers to three 600-h.p. two-cycle Koerting engines operating in Central Indiana on producer gas.

2 In answer I would say that I cannot furnish further information. The statistics in regard to fuel consumption indicate that these engines are actually operating on 10,000 B.t.u. per brake horse power hour. The engines are unquestionably not of the best type, as is evinced by the fact that their manufacturers have withdrawn them from the market and substituted a much better engine. I understand the makers are now putting out engines consuming around 8000 B.t.u.

3 Mr. Parker refers to figures for the two power plants in central Indiana, where it is stated that a gas power plant carrying an average power load of 1320 b.h.p. uses .95 lb. of coal per b.h.p., whereas a steam power plant at the same factory carrying an average load of 1250 b.h.p. uses 5 lb. of coal per b.h.p. It will be seen that I further brought out that the gas plant uses 1.34 lb. per b.h.p., considering auxiliaries, so that the ratio of coal consumption of the two plants is 1 to 3.8 in favor of the gas plant. Mr. Parker brings out the point that the average ratio as shown by government tests is 2.7, and I agree with him that this figure more nearly represents average conditions than the one which I state. I simply gave statistics of one particular instance, representing two actual equipments operating side by side at the same factory.

4 Mr. Parker questions whether the costs for labor given in Par. 11 are not too low. They undoubtedly are lower than average figures throughout the country. They are perhaps lower than they should be. They are, however, accurate, I believe, for the instance in question, and represent what is actually paid at that particular power plant.

5 He also raises the question as to why there should be such wide variation in the cost per horse power in gas power plants, ranging in the figures I gave from $55.00 per horse power to $100.00 per horse power. There is a very wide range in cost between small and large power plants and the decrease per horse power for the bituminous plants is very rapid, up to about 5000 horse power, and beyond that figure the cost per horse power is approximately constant. Further

the 20,000 h.p. plant referred to where the cost is given as $55.00 per horse power was an auxiliary power plant in connection with a water power plant. It was therefore rated at its full maximum and had no reserve or spare unit, as the plant itself was a spare unit. Under ordinary circumstances this equipment would be rated at perhaps one-third less. Further, the cost varies with the fuel used,—the poorer the fuel the more expensive and more extensive the equipment required. In general I would say that the cost of a bituminous producer equipment is such that it will not be used extensively in sizes below 500 h.p. excepting in localities where the use of anthracite coal is out of the question. Under usual conditions for power plants under 500 h.p., the anthracite suction producer presents a better proposition than the bituminous producer, as it is much simpler and less expensive.

6 Mr. Bibbins draws the issue between the processes of generating producer gas by one of the other of which the tar is burned from the gas in the producer and by which the tar is removed by mechanical means. The term "tar-laden gas" does not apply unless it be to gas supposedly burned free of tar, but in reality, on account of faulty apparatus or operation, carrying tar. When gas is cleaned by mechanical process and really cleaned, it is "tar-free," but it carries that other rich hydrocarbon which is not condensable, viz: CH_4.

7 What I claim is this: that when it is attempted to burn the tar from the gas during the generating process there are three drawbacks which have retarded the use of producer gas from bituminous coal. These are as follows:

- *a* In order to burn the tar from the gas continuously without clogging the fuel bed or the apparatus and at the same time actually clean the gas, it is necessary to use two generators and alternate or reverse the draft in the generators. This involves too great first cost; hot operating parts, hard to keep in repair; too much skill for operation.
- *b* With only one generator the process is too critical for ordinary operating conditions. While it may be carried on successfully under expert supervision and undoubtedly has been in several instances, it is always subject to failure in case of clogging of apparatus or failure to produce clean gas.
- *c* Gas cleaned by burning out the tar averages lower in B.t.u. per cu. ft. than when the tar is removed by mechanical

means, and the lighter non-condensible hydrocarbons left in the gas. The average figures range from 80 to 110 B.t.u. for the tar burning process, and 125 to 160 B.t.u. for the process where the tar is mechanically removed. For power purposes the lower value gas may give as good efficiency as the higher, but it has less capacity and larger apparatus is required than with the higher value gas. It should be emphasized, however, that the use of producer gas is not confined to the generation of power. The gas can be used for all lines of industrial work in large and small heating furnaces, and the field for producer equipment in this direction is probably larger than in connection with power plant equipment. At the present time producer gas is used for many heating operations, the principal drawback being that the gas has not sufficient flame temperature for welding and melting and other similar high heats except where regeneration is employed. But in this respect the possibilities of gas averaging 140 heat units are far greater than the possibilities of gas averaging 100 heat units, and I take the position that every development which increases the heat value of producer gas is a decided step in advance.

8 I further claim that the updraft bituminous gas producer, which generates a gas tar-laden only until the tar is removed mechanically, is a practical plant, easily operated continuously by laboring men, and that it is not likely to be clogged or shut down in case operation is not properly carried on; in other words, the plant meets ordinary conditions. If it is efficiently operated it gives the best of results. If it is operated poorly, it gives comparatively poor results, but inefficient operation does not result in complete failure or shutdown. In this respect the updraft bituminous producer is comparable with a boiler plant, and it is hardly an exaggeration to say that this apparatus deserves to be characterized as practically "foolproof."

9 Mr. Bibbins calls attention to the serious drawback of the production of tar without adequate means of handling it or disposing of it. His point in this respect is well taken. Anyone familiar with a plant where tar of this character has been allowed to accumulate without provision for its handling and disposition will recognize the importance of the subject. If it were not possible to provide adequate means, this would prove a serious objection, possibly strong enough to condemn this type of apparatus.

10 However, the handling and utilization of this tar is not a difficult problem. The tar at ordinary temperatures is a stiff, gummy substance almost impossible to handle, but if slightly heated it becomes liquid and can be disposed of by apparatus similar to fuel oil apparatus. This apparatus not only provides for the disposition of the tar, but for utilizing it in generating power for the operation of the plant. It must be recalled that it is only within the last two or three years that such apparatus has been produced and there are today only a few operating plants. While these are completely successful, they do not embody in every respect all the economies which will ultimately become possible. However, progress enough has been made safely to predict that sufficient steam can be generated with this tar for gas making, for producing power for moving the gas, and the heat necessary for handling the tar itself, in which case the tar would come very near providing for the entire auxiliary plant.

11 I agree with Mr. Bibbins that operating an engine on producer gas is a very different affair from operating on natural gas. However, I have called attention to the fact that five 100-h.p. gas engines operating at Elyria, Ohio, are piped both for natural and producer gas and they operate on either gas without change in compression at the option of the engineer. The producer gas pipes are larger than those for natural gas and when a change is made from one gas to the other the valves are adjusted, but this does not interrupt the operation or cause fluctuations at the voltmeter.

12 The point is important simply because in many cases where engines are operating on natural gas the gas is expensive or the supply is giving out and the question arises as to whether producer gas can be substituted.

13 In reference to Par. 11, I do not see how Mr. Bibbins arrives at the conclusion that there was a coal consumption of 50 lb. per sq. ft. per hour. In the plant in Indiana carrying an average load of 1320 h.p., there are five gas generators connected in one battery with a total generating area of 250 ft. They usually operate three of these, employing a total area of 150 sq. ft. The figures given show a coal consumption amounting to 1760 lb. per hr. indicating a consumption per square foot per hour of a little less than 12 lb. This I would say is a normal condition for a bituminous plant operating at two-thirds to three-quarters load. As a matter of fact I would consider 25 lb. per sq. ft. as a maximum consumption, and 15 lb. per sq. ft. as normal for producers of this type.

THE SURGE TANK IN WATER POWER PLANTS

By R. D. Johnson, Published in June Proceedings

ABSTRACT OF PAPER

This paper treats of the momentum of flowing water in long pressure pipes for the supply of hydraulic turbines or impulse wheels and of the control of rate of flow by modifying the momentum in such manner as to obviate harmful effect upon speed regulation of the water-wheels, *without waste of water through relief valves, deflecting nozzles or by-passing it*, as has usually been thought unavoidable where pipes are long, velocity great and pressures high.

This is accomplished by a surge tank near the down stream end of the pressure pipe, atmospheric or under compressed air.

The paper treats of the size of surge tank needed under various conditions of velocity, size and length of the moving water column, and presents a novel device by which the diameter (or area) of the tank may be reduced about one-half, thereby lessening its cost and at the same time improving the pressure regulation for speed control. This device is called the "Differential Regulator" and it may work open to the air or under compressed air where head is high and support lacking. The design of the regulator is fully set forth in this mathematical relation to the balance of the plant.

DISCUSSION

Chester W. Larner[1] Reverting, in conclusion, to Mr. Johnson's equation [7] it has been shown that this equation without modification gives values of y_{max} too small, and when modified by

[1] Continuation of discussion in The Journal for October, which also contains other discussions of this paper. It should here be noted that the symbol V_{max}, which was adopted from the author's paper, is not strictly accurate in the sense in which it is used. It is used to represent the maximum velocity during the first part of the cycle up to the time when demand and supply become equal. It is not the actual maximum penstock velocity, however, as this occurs later in the cycle, V'_{max} is the correct term but both are synonymous as used.

the substitution of V_{max} (or V'_{max}) for V_2, as was done by him in Par. 87, it gives values too large. Obviously there must in every case be some intermediate value of V' which if substituted for V_2 will give the true value of y_{max}. Since when V'_{max} is used the overrun is due to the variation of V', which the equation does not consider, it follows that this value V'' will lie between V'_1 and V'_{max}. In mathematical terms

$$V'' = V'_1 + K\,(V'_{max} - V'_1) \qquad [3]$$

where K is a coefficient less than unity. Since K cannot be determined from theoretical considerations it only remains to be seen if it can be determined with a fair degree of accuracy by any empirical law. If so we should obtain greater accuracy in the use of Equation [7], which would then become

$$y^2_{max} = \frac{RL}{g}\,(V'' - V_1)^2 + c^2\,(V''^2 - V_1^2)^2 \qquad [7']$$

115 Fifteen problems covering a wide variation in the values of R, L, c, and percentage of load increment have been solved by arithmetical integration and the results, together with the assumed conditions, are given in Table 1. Values of V'' were obtained by substituting the values of y_{max} found by arithmetical integration in Equation [7′] and solving for V''. Values of K were obtained by substituting

TABLE 1 RESULTS BY ARITHMETICAL INTEGRATION AND CORRESPONDING VALUES OF K

Assumed Conditions							By Arithmetical Integration at Intervals of one sec.					
Ex	h	R	L	V_1	Load Change Per ct.	c	V'_1	V'_{max}	y_{max}	V''	K	$\frac{RL}{c}$
1	150	0.1	2000	11	20	0.1	13.20	14.18	9.56	13.72	0.53	2000
2	250	0.1	2000	12	15	0.2	13.80	14.78	14.84	14.34	.55	2000
3	300	0.2	2000	12	20	0.05	14.40	14.95	10.78	14.85	.82	8000
4	400	0.2	3000	13	15	0.1	14.95	15.42	11.62	15.25	.64	6000
5	500	0.2	6000	14	10	0.15	15.40	15.82	12.61	15.66	.62	8000
6	300	0.25	4000	12.5	15	0.1	14.38	15.21	15.64	15.02	.77	10000
7	500	0.25	10000	13.5	10	0.15	14.85	15.43	17.69	15.31	.79	16667
8	300	0.3	4000	12	15	0.05	13.80	14.55	15.10	14.42	.82	24000
9	500	0.3	10000	13	10	0.1	14.30	14.84	17.60	14.75	.83	30000
10	150	0.1	4000	13	10	0.1	14.30	15.33	9.00	15.00	.68	4000
11	500	0.3	5000	12	13	0.15	13.56	13.99	14.74	13.88	.74	10000
12	100	0.3	2000	13	13	0.05	14.69	19.63	22.95	18.00	.67	12000
13	200	0.227	5000	13	6	0.1	13.82	14.51	8.80	14.35	.77	11300
14	200	0.227	5000	12.5	15.5	0.1	14.44	16.47	22.77	15.95	.74	11300
15	200	0.227	5000	13	12	0.1	14.54	16.13	18.07	15.73	.75	11300

the values of V'' thus found in equation [3]. V'_1 is the initial value of V' and is, of course, V_1 increased to correspond to the additional load.

116 The values of K vary considerably, and after investigation it was found that K is a fairly consistent function of $\frac{R\,L}{c}$, the values of which are given in the last column of Table 1. When these points were plotted on coördinate paper and a rough curve drawn through them, the curve bore a general resemblance to the upper left-hand quadrant of an elipse with major axis horizontal. The relation between K and $\frac{R\,L}{c}$ was therefore assumed to be of the form

$$Ax^2 + By^2 + Dx + E\,y + F = 0$$

where

$$x = \frac{RL}{1000\,c} \quad \text{and} \quad y = K$$

117 Since we are dealing with undetermined coefficients this may be written

$$Ax^2 + By^2 + Dx + Ey + 1 = 0$$

thus eliminating one of the constants. This equation can be solved by the Method of Least Squares, but a solution involving four unknown quantities is so laborious that it seemed desirable to eliminate some of them if possible. By inspection of the preliminary curve it appeared that the center of the ellipse would fall on or near the point $P \equiv (30,\ 0.50)$. The coördinates of the center of the ellipse, expressed in terms of the unknown constants, are $x = -\frac{D}{2A}$ and $y = -\frac{E}{2B}$. Hence

$$-\frac{D}{2A} = 30 \text{ and } -\frac{E}{2B} = 0.50$$

$$D = -60A \qquad E = -B$$

Substituting

$$Ax^2 + By^2 - 60Ax - By + 1 = 0$$

118 Inserting values of x and y from Table 1 we have fifteen observation equations from which by the Method of Least Squares are obtained the two normal equations whose solution gives us the values of A and B for the empirical equation sought. After simplifying we have

$$x^2 - 60x - 7023.78\,(y - y^2) = -1872 \qquad [4]$$

which is the most accurate expression of the assumed form obtainable from the fifteen examples upon which it is based. The curve of this

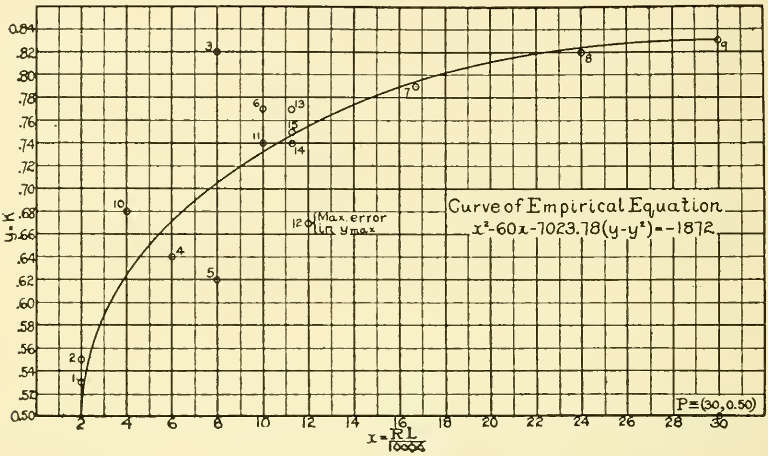


FIG. 14 CURVE FOR DETERMINING K IN EQUATION 3

equation is plotted in Fig. 14 from $x = 2$ to $x = 30$, or from $\frac{RL}{c} = 2000$ to $\frac{RL}{c} = 30\ 000$. This is the full scope of the equation and it must not be applied to values of $\frac{RL}{c}$ outside these limits. It is believed that nearly all practical cases will lie well within them.

119 The observation points are also shown in Fig. 14, and it should be noted that in individual cases the true value of K may vary considerably from that shown by the curve without affecting y_{max} very greatly. For instance point No. 3 lies farther from the curve than any other and yet the error in Example 3 as shown in Table 2 is only 2.4 per cent.

120 Table 2 gives a comparison of the values of y_{max} deduced by each of the three methods thus far developed.

121 My values were determined by substituting in Equation [3] the values of V''_1 and V''_{max} from Table 1 and K from the curve of Fig. 14. The value of V'' thus obtained was substituted in Equation [7'] which was then solved for y_{max}. By the "author's method" in the table is meant the method which he uses in Par. 85 to 88 where he substitutes V_{max} for V_2 in Equation [7]

122 In using Mr. Harza's Equation [20] I have given V_2 the value of the final quiescent velocity, which I understand to be the correct interpretation.

123 Table 2 shows that my method gives an average error of 1.5 per cent, Mr. Harza's method 5.1 per cent, and Mr. Johnson's 12.2 per cent. My maximum error is 8.4 per cent, Mr. Harza's 27.3 per cent, and Mr. Johnson's 33 per cent. That this method will in

TABLE 2 COMPARATIVE RESULTS BY VARIOUS METHODS PRESENTED

Ex.	True value of y_{max} by Arith. Integ.	Writer's Method using Equation [7] with $V_2 = V''$			Author's Method using Equation [7] with $V_2 = V'_{max}$		Harza's Method using Equation [20] with V_2 = final quiescent velocity			V_2 for Equation [20]
		y_{max}	Error per cent +	Error per cent −	y_{max}	Error Per cent +	y_{max}	Error Per cent +	Error Per cent −	
1	9.56	9.44	......	1.2	11.28	18.0	9.88	3.4	.....	14.18
2	14.84	14.50	......	2.2	17.90	20.5	12.08	......	18.7	14.80
3	10.78	10.52	.....	2.4	11.15	3.4	10.61	.....	1.6	14.57
4	11.62	11.71	0.8	......	12.51	7.7	10.13	......	4.2	15.20
5	12.61	12.85	1.9	......	13.75	8.9	11.72	......	7.1	15.65
6	15.64	15.46	......	1.1	16.87	7.8	15.64	0.0	0.0	14.68
7	17.69	17.76	0.4	.....	18.92	7.2	17.54	....	0.8	15.06
8	15.10	15.12	0.1	.....	15.94	5.6	15.23	0.9	....	13.92
9	17.60	17.60	0.0	0.0	18.50	5.0	17.63	0.2	....	14.42
10	9.00	8.73	......	2.9	10.56	17.2	9.14	1.6	....	14.89
11	14.74	14.71	......	0.2	15.67	6.3	14.17	......	3.9	13.75
12	22.95	24.92	8.4	.....	30.55	33.0	16.69	......	27.3	15.21
13	8.80	8.72	.....	0.9	9.90	12.5	8.48	.....	3.6	14.00
14	22.77	22.77	0.0	0.0	26.20	15.2	22.12	......	2.9	15.00
15	18.07	17.99	......	0.4	20.70	14.5	18.00	......	0.4	15.00
		Average error = 1.5% Max. " = 8.4%			Average error = 12.2 % Max. error = 33.0 %		Average error = 5.1% Max. " = 27.3%			

general give much more accurate results than either of the others is, I believe, obvious. It is, however, more complicated and its use involves some difficulties which can best be explained in the solution of a practical example.

124 Suppose, for example, we wish to design an open surge-tank for a plant which is to develop 40 000 h.p. at full load under a head of 372 ft. The penstock is to be 8000 ft. long and under a 20 per cent sudden increment of load the surge must not exceed 25 ft.

125 The full load velocity in the penstock must be determined from considerations of economy in installation and operation which need not be discussed here. Let it suffice to say that in this case we have determined upon a full load velocity of 11.5 ft. per sec. At this velocity it will require a penstock approximately 12 ft. in diameter to supply the full load demand under the working-head. According to Williams and Hazen's formula for riveted steel pipe ten years old the friction loss will be 24 ft. for a velocity of 11.5 ft. from which $c = 0.1815$.

126 In order to cover the worst conditions we must design for a velocity change from V_1 to V_2 with the highest actual value of V_2. Consequently V_2 must be the full load velocity or $V_2 = 11.5$. We must now determine V_1 such that when the load is increased 20 per cent the steady velocity in the penstock after all surging has ceased will be 11.5 ft. per sec. Tabulating values

$$V_2 = 11.5 \text{ ft.} \qquad L = 8000 \text{ ft.} \qquad y_{max} = 25 \text{ ft.}$$
$$c = 0.1815 \qquad h = 372 \text{ ft.} \qquad \text{Load change} = 20 \text{ per cent}$$

Now

$$V'_1 (h - cV_1^2) = V_2 (h - cV_2^2)$$

and

$$V'_1 = 1.2\ V_1$$

Substituting

$$1.2V_1 (372 - 0.1815\ V_1^2) = 11.5\ (372 - 0.1815 \times 11.5^2)$$
$$V_1 = 9.37$$

The problem now is to find R.

127 In order to apply Equation [7′] we must first find V'' which, however, according to Equation [3] depends upon K which in turn depends upon R. Obviously in order to make a correct solution we must assume the correct value of R in determining V''. It is practically impossible to do this except by a succession of trial values and hence it will usually take several solutions to determine the true value of y_{max}. In fact I regard this equation as of more value in testing values found by other methods than for original work.

128 In order to get as close a trial value of R as possible let us take Mr. Harza's Equation [20] and solve for R. Substituting

$$625 - 744 \times 25 = -2R \left\{ \frac{8000}{64.4} \times 44.45 + \frac{372 \times 49.49}{3.14 \sqrt{R}} \times 2.13 \right\}$$

$$R = .33$$

Using this as a trial value

$$\frac{RL}{1000\,c} = \frac{.33 \times 8000}{1000 \times 0.1815} = 14.5$$

From the curve Fig. 14, $K = 0.778$.

We must now determine V'_{max}. It may be figured from either V_1 or V_2. The equations are

$$V'_{max} \quad \frac{1.2\,V_1\,(h - c\,V_1^2)}{h - c\,V_1^2 - y_{max}} \quad \text{or} \quad \frac{V_2\,(h - c\,V_2^2)}{h - c\,V_1^2 - y_{max}}$$

In either case $V'_{max} = 12.085$. Then from Equation [3]

$$V'' = 11.244 + 0.778\,(12.085 - 11.244) = 11.898$$

From Equation [7′]

$$y^2_{max} = \frac{0.33 \times 8000}{32.2} \times 6.3908 + 95.225$$

$$= 523.97 + 95.225$$

$$= 619.20$$

129 The correct value of y^2_{max} according to our hypothesis is 625. Therefore the right-hand side of the equation is 5.8 low showing that the value of R should be increased a little. Since the increase will not affect K appreciably we must arrange to add to the first term only. This term varies directly as R and hence the new value of R should be

$$R = \frac{0.33\,(523.97 + 5.8)}{523.97} = 0.3337$$

Solving again

$$\frac{RL}{c} = 14.65$$

from which $K = .779$ and $V'' = 11.90$

$$y^2_{max} = \frac{0.3337 \times 8000}{32.2} \times 6.3908 + 95.23$$

$$= 529.77 + 95.23$$

$$= 625$$

$$y_{max} = 25$$

which is the desired value.

130 Integrating the curve arithmetically with $R = 0.3337$, I find $y_{max} = 25.08$ showing that the value found by Equation [7′] was about 0.3 per cent low. R should have been a trifle less and it may

be that the value $R = 0.33$ found by Equation [20] is nearer the truth than my own. Certain it is that both equations are very close and an error of 0.3 per cent is not worth considering. From a practical standpoint the re-adjustment in the value of R was scarcely necessary. It was made to illustrate the best method to pursue in cases where it is necessary to make a correction.

131 In view of the close results shown by Mr. Harza's Equation [20] in the problem just solved and in the other fifteen examples I think it but justice due him to say a word in praise of this equation. For an equation containing at least one, if not more, arbitrary assumptions it shows a surprising degree of accuracy under a wide variety of conditions. In every instance it is more accurate than the author's Equation [7]. The average error is less than half that of Equation [7]. In fact were it not for the two instances where the error runs up high I should consider my own method an unnecessary refinement. There are two cases, however, where the error is 19 and 27 per cent respectively, showing a possible deviation which ought to be provided against. The former case is a perfectly normal one although in fairness it should be said that the latter case is not a normal one and would probably never occur in practice. Its introduction, however, is no more unfair to Mr. Harza's method than to the other two. Another point of merit in this equation is that it is the only one so far presented which states in simple terms and with fair accuracy the relation between the maximum surge and the initial and final quiescent velocities.

132 In conclusion I wish to emphasize the fact that throughout my discussion V_2 has had but one meaning, namely, the final quiescent velocity in the penstock after all surging has ceased. This interpretation is based upon the author's statement in Par. 35 that "$V_2 - V_1$ is the ultimate change in velocity due to the load change." Hence V_2 must be the ultimate velocity due to the load change and assuredly that is the final quiescent velocity. To my mind no definition of the word "ultimate" can possibly justify its application to an intermediate momentary value during the surge such as V'_{max}.

AUTHOR'S CLOSURE

The Author. The purpose of my little monograph on Surge Tanks was to awaken some much-needed enthusiasm on the subject, and to call forth discussion and adverse criticism, in the belief that the resulting matter when coördinated would not only add to my own

store of information, but present a collection of ideas sufficiently varied to enable any interested student, to separate the wheat from the chaff and arrive at a correct understanding of these complicated phenomena. The outcome thus far is highly gratifying, but still a long way from the result sought. Mr. Larner's work particularly is of great practical value.

2 My paper was prepared at very short notice and is decidedly incomplete when considered in the light of a text-book, and deficient in what might be instructive examples as to the limitations of its equations. After persual of the work of my critics, I want to say at the outset, however, that I find absolutely no reason for altering any of my equations, unless it were to make them universally exact, a difficult task which has not been done in the discussion, as I shall proceed to show. Equations 7 and 12 called forth the most comment, and therefore I shall devote myself to a short general discussion of these two equations in the light of criticism. They are just what they purport to be, nothing more nor less, and their accuracy according to the preliminary assumption is unquestionable. Both of them assume a constant draft velocity as the superior limit of the integration, and hence have only an indirect value when applied to an actual case where the draft velocity varies (particularly in the simple tank regulation) according to the action of the governor in its effort to maintain constant power. I described this effect at great length, and yet the language of my critics in some passages would convey the impression to any but a very careful reader, that I had overlooked this point and attributed to my equations a perfection entirely unwarranted by facts.

3 Mr. Larner says in Par. 66 that he is unable to perceive the logic of developing such an equation as 7, and yet he offers nothing better which is usable; and he adopts Mr. Harza's Equation 20, which I shall show later gives less satisfactory results for some cases than Equation 7. I have intended to claim no exact application for this equation, which avowedly neglects the action of the governor (Par. 37). Mr. Harza does claim rather exact application for his Equation 20. The fact of the matter is that this Equation 7 is extremely useful, and sufficiently accurate if judiciously used by one who makes a study of the subject and learns to know its value. Professor Church has proceeded logically to show its limitations, and this is a good step. But as will be shown, he has not worked the equation to its best advantage, because he has not mentioned the fact that the final quiescent velocity, after all surging has ceased, may be *known before*

hand as well as the immediate value of 8 ft. per second. Mr. Harza's novel way of introducing the governor action is undoubtedly a valuable step in advance of my work, and is in the right direction.

4 Equation (12) deals primarily with a *velocity change* between two limits V_1 and V_2. It is therefore directly applicable only to the particular large velocity change for which the design is made, and beyond which one is supposed to care nothing about close regulation. When the design is adequate the surge is often a very small proportion of the head, and obviously should be so, because otherwise one would have to provide a much larger water wheel than necessary for the purpose of holding up full load during the depression of the surge, and the wheel would afterward be continuously operating at a large reduction of gatage and at poor efficiency. Therefore, it often happens, especially in designs for large plants, that the superior limit of V_2 is not largely different from the value to which the velocity instantly changes when more load is demanded; it is always more accurate, however, as I pointed out in Par. 55, to increase this value by multiplying it by $\frac{h}{h-y_1}$ before introducing it in the equations.

5 Mr. Larner has made this off-hand statement of mine the bone of contention in his arguments; I want, therefore, to point out the practical reasonableness of my statement, as well as its accuracy, and thereby show that the consideration of the change of gradient, of which Mr. Larner makes such a point, does not naturally or necessarily enter into the question. Curiously, the same error of neglecting the change in gradient which he attributes to me, he himself makes, at least partially, when he states that its effect upon the surge in the simple tank is practically nil (Par. 62*a*). (See also Par. 35, 73 and 74.)

6 As stated in my Par. 55, "h" is the "working head," which means to me the net head for a velocity of V_1 although to Mr. Larner it seems to mean the gross head. I myself never use the term in that way. Suppose the full load capacity of our plant is 50 000 h.p. and one wants to provide for a maximum sudden increment of load of 5000 while running at 45 000 h.p. output. The first step is to make a computation for the working head at 45 000 h.p. output. The actual value of "h" within reasonable limits does not ordinarily affect much the value of $\frac{h}{h-y_1}$ if "y_1" is not more than 5 per cent of h, as is often the case. One may easily compute "h" by trial with more accuracy than that with which one can foretell the friction value, and with

much more refinement than is perhaps warranted by one's knowledge of the future maximum load change and the water wheel efficiency.

7 Having selected "h," then V_1 follows from it, or one might say is selected with it, for the working head is the gross head less CV_1^2. Now, if the head and wheel efficiency did not vary, the value of V_2 would be $\frac{50}{45} V_1$. It is customary to neglect the change in wheel efficiency, but it is always more accurate to increase V_2 thus found by assigning to it a larger value, which is occasioned very suddenly in the differential regulator on account of the dropping off in head an amount "y_1" which one selects. The correct value of this increased V_2 to be used in Equation 12 is, as stated, $\frac{V_2 h}{h\text{-}y}$. (See Mr. Larner's Par. 94.)

8 In all my work V_2 is not *any particular velocity* but simply the *superior limit* in my integrations under the hypotheses. The use one makes of it in an actual case depends upon individual knowledge of the question, and is purely a matter of judgment. In the premises (Par. 85) I have assigned very plainly a value of $V_{max} = 15$, as this superior limit for the numerical examples, merely as an illustration of the fact that V_2 may be given that value. It naturally gives more accurate results for Equation 12 than for 7, and I am perhaps subject to criticism for using this value in Par. 87 instead of some smaller value, but not knowing the correct figure to use for the best result except by arithmetic integration, I used that figure as an illustration, expecting the result to be on the safe side and not far from the truth. In applying Equation 12, in Par. 91, I have used the value of 15 for V_2 as plainly as I am able to state it, and V_2 in the premises is taken as V_{max}, which may always be obtained by multiplying by $\frac{h}{h\text{-}y_1}$ as stated.

9 I am dwelling upon this at length because in his able discussion Mr. Larner has misinterpreted the ideas which I set forth. His paper is a valuable one because it is accurate, so far as I have checked it, and it gives a good airing of the subject, but nearly all of his work is curiously illustrative rather of improper and inconsistent uses of the equations than of the incorrect use for the best approximate results. For example, he states in Par. 105 that if the correct value for V_{max} be used as the superior limit in Equation 12, then the resulting values will be correct; by which he means correct for his case 4, as one may easily determine by reading his development of a "true

theoretical equation" (Par. 91). If then V_{max} is determined as I pointed out in Par. 55, and used as the superior limit in Equation 12, the resulting equation is a "true theoretical one," according to Mr. Larner, and indeed I myself nearly concur in this opinion. Referring now to Par. 49, he states that Equation 12 is applicable only to Cases 1 and 2 (see Par. 80). Also, in his comparative example by arithmetical integration, illustrated in Fig. 4, he gets a value for V_{max} of nearly 16, and still he claims that because by so doing he attains a surge of 15.3, my formula is wrong, since with $V_{max} = 15$, I obtained 10 ft. as the value for y_{max}. The only conclusion I can reach from this is that the equation will not apply where it is supposed to apply, as stated by Mr. Larner in Par. 86.

10 Mr. Larner's reference, in some instances to the "author's contention," etc., refer to hurried answers to questions asked in correspondence. So far as I know my statements were consistent and if not I could possibly explain them. In Par. 95, Mr. Larner states that my Equation 12 is the same as what he terms his Equation 2, provided one uses the correct value for V_{max}. Inasmuch as there seems to be no particular reason for not using the correct value, the originality of Equation 2 seems to lie only in that it contains rather a condensed means of computing the various power outputs from the existing heads, allowing for friction; which is elementary and not an essential in Equation 12.

11 As to Mr. Larner's criticism (Par. 83) of my formula for port area, I agree that it is not theoretically exact except under the hypotheses stated in Par. 48. Here again, however, he writes out an equation which is exactly the same thing as my own, if one substitutes V_{max} for V_2, and therefore his equation contains the same fault as my own.

12 It is quite true that the area by this formula is a little large, but as stated in Par. 54 it is better to err on that side. In order to produce an ideal set of curves for the problem in Par. 91 the port area would have to be reduced by perhaps one-twentieth. The accompanying curves show the result of a design as in Par. 91 with the port area thus reduced.

13 For this work the area of the stand pipe was taken as 25 sq. ft., and $R = 0.25$ to facilitate the computations; also the port area was made sufficient to pass 60 c.f.p.s. under a head of 1 ft. The choking head at the entrance to the conduit is neglected, as is quite reasonable in this case if the surge pipe is slightly flared below the ports where it joins the conduit. Inasmuch as Mr. Larner has not produced a set

of curves illustrative of the problem he was studying, I thought this addition to his work would be interesting. His curves all represent possible cases and are therefore very instructive—but they have no value as a check on Equation 12, because his premises are different from those assumed for the problem as computed with the formula.

14 An examination of the surge pipe pressure curve shows quite a wide departure from the theoretical rectangular curve assumed in Equation 12. One might, therefore, expect considerable error in its application to such a curve. This is not the case, however, for

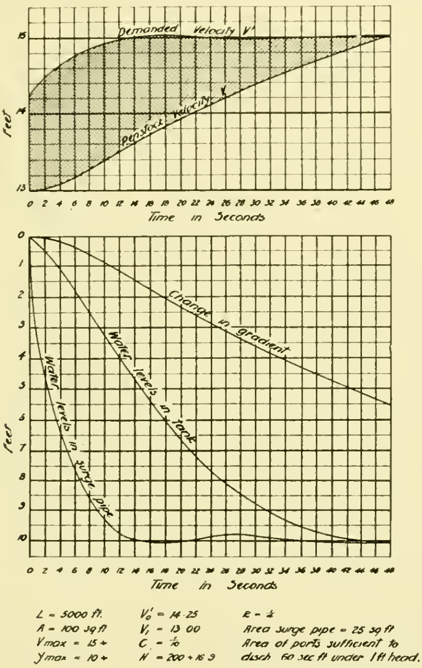


FIG. 1 CURVES ILLUSTRATIVE OF PROBLEM REFERRED TO IN PAR. 12

usually no appreciable error is to be discovered in a practical working example. The reason for this apparent contradiction seems to be very well explained by the fact that the time is longer than that found for the hypothetical cases, and hence the lagging in the first part of the cycle is recovered by an extension of time at the end. Furthermore, in the actual case there is a relief from some of the work contemplated in the hypothetical case due to the fact that the demand is not instantly changed to its maximum value. The shape of the pres-

sure curve here illustrated is strictly typical of an ideal curve, as I have found in dozens of cases. There is always noticeable that arch effect in the horizontal portion of the curve.

15 I want to say in justice to Mr. Larner, lest the inference be drawn that I undervalue his excellent work, that in all instances his conclusions and adverse criticism are justifiable from his point of view, and in many instances from my own, on account of a vagueness and incompleteness of explanation on my part, which I can clearly see in the light of his analysis. He has tried to set forth not so much his own opinion of what I have intended to show, as his idea of how I should have expressed myself to make my meaning clear to one less qualified to discern than himself. At least, that is my idea. It is none the less necessary to point out the intent of my meaning, in a forcible way, both, in justice to myself and for the further clearing up of a number of quasi-disputed points.

16 It is gratifying to note the close agreement between Mr. Harza's formula and the preliminary ones in my paper, and it is to be hoped that his work of analyzing and checking will be continued to include the differential principle, and the use of compressed air.

17 I have not given the attention to the simple stand pipe that Mr. Harza has, because I have always regarded the methematics relating to it as simply a step toward the discovery of a regulator which would meet more perfectly the requirements of practice. Such a regulator, I believe, is to be found through a study of the "differential principle," and I have yet to be convinced that the regulator I propose is not far better than the simple stand pipe, despite Mr. Harza's argument somewhat to the contrary. His reasoning, in the abstract, I believe is sound, but it shows a possibility of modification after more detailed study of the question with the essential aid of definite dimensions, which may be found by tedious arithmetic processes of integration. The *tendency* to produce worse regulation conditions by the introduction of a resistance between surge tank and conduit certainly exists, and is due to conditions very much as stated by Mr. Harza—an appreciable bad effect upon regulation never gets to the point of appearing, however, because lost sight of when compared with the manifest advantages. Mr. Harza shows a realization of the possibility of this condition in Par. 47. I have no doubt that further study of the question on his part will largely clear up this slight difference of opinion.

18 I have never hit upon a method of approximation, such as Mr. Harza's Equation 20, which I regarded as accurate enough to

publish, and was compelled to leave the effect of the governor's action to the judgment of the designer in selecting his value of $V_2 - V_1$. I regard his equation of especial value as proving how little practical effect the governor's action has, in some instances, *when the other conditions* for good regulation are satisfied.

19 Another reason for my not giving much attention to the governor action is that it does not enter into the problem in the same way when the differential principle is used. In this case, it is necessary only to select a value for V_2 in excess of that which one *expects* to represent the maximum load change in the future plant, as pointed out in Par. 55.

20 As to the argument (Par. 36) against catching all the energized water, I should like to point out two things: First, it does not appear clear to me that curtailing the upward surge, whose maximum occurs for rejected loads, puts any limit on the downward surge, whose maximum occurs for demanded loads, except where a super-added or a perpetual wave exists. The latter condition is possible where the differential action is omitted, and where one is really designing for minimum size of tank consistent with regulation requirements. In that case, water would continue to spill at regularly recurring intervals all day, or until another load change happened to occur in such a way as to fit into the existing wave and smother it. Mr. Harza had in mind the "super-added" wave, but even this is far more likely to occur when the differential action is omitted. It was probably not intended to imply the possibility of such an obviously poor design when arguing its advantage.

21 Second, the saving of water at the rare intervals of "full load rejected" is not of much consequence, to be sure; but the saving of the cost of construction work necessary to catch and lead away a possible large discharge due to a shut-down is of such importance as to weigh decidedly in the balance against the additional cost of surge tank to catch and hold all the energized water. Allowing the water to spill over has a damping effect upon surge waves for rejected loads, as he states, but this can be accomplished much more effectually by means of the differential principle without waste of water and usually at a saving in cost besides. It is possible, through such a regulator, if designed especially for maximum damping effect, to make the surge wave strictly and absolutely dead beat; and the importance of a thorough study of this principle cannot be overestimated.

22 Referring now to Mr. Harza's Par. 49, I want to say in justice to Mr. Warren's valuable paper that my remarks were not intended to

attain the dignity of a criticism, but merely as introductory to a line of argument which seemed to be new to him. I am still of the opinion that a properly designed regulator, or system of regulators, is actually "a complete remedy for the troubles in speed regulation caused by the excessive inertia of a water column." Mr. Harza means, I judge, that the surge tank cannot be made a complete remedy for variation in head—but it is obvious that a moderate amount of head variation does not at all mean "troubles in speed regulation;" for otherwise, where do his own equations lead? His criticism of my work is very creditable and fair, it seems to me. The values obtained by my Equation 7 are not as close to the truth, in the instances cited, as those obtained by his Equation 20, as might be expected; although, as I shall show later, Equation 7 gives closer results when applied to Professor Church's examples.

23 These problems contain an inordinate amount of friction, which is rarely more than 10 per cent for a correctly designed plant, and often as low as 5 per cent, but I use them for the sake of illustrating the inconsistency of Mr. Larner in making the statement that friction may be disregarded (Par. 52) and at the same time calling me to account (Par. 89–95) for disregarding the change in gradient, where this mistake was due to his misinterpretation. In Par. 89 he intimates that persual of my paper would disclose the fact that the superior limit of the velocity in my equations, which I have called V_2, is invariably intended to be applied to the constant quiescent velocity, or the final value of the velocity after all surging has ceased, and steady running conditions are once more established at the new load value. Granting for the moment the reasonableness of such a conclusion, one notices that Professor Church must have used something more than "ordinary care," for he does not substitute such a value for V_2. If he had done so, however, the results would have been fairly good in the examples cited, and therefore in these instances it would have been better to do so, but not always by any means. V_2 is naturally the "ultimate" velocity under the assumption of a constant draft velocity (see Par. 35).

24 Let us adopt Professor Church's nomenclature for this little study, with the addition of V_3 which he does not use but which I need as a symbol for the steady velocity under the new load after all vibrations have ceased. Let H be the whole head; then from the principle of constant power we have, neglecting the change in wheel efficiency

$$(H - CV_1^2)\, V_0^1 = V_3\, H - CV_3^3 \qquad (23)$$

also $C\ (V_1^2 - V_3^2)$ = the net change in gradient or the difference in head before and after the surge, which one may call Δh.

25 Now a very little thought at this juncture will disclose the fact that $y_{\max}$ must be at least as great, in all cases, as Δh; it is also nearly as plain, I think, that $y_{\max}$ is always greater than Δh; however, for my present purpose, I am content to stop with the former statement which admits of no argument, for I propose to solve for V_3 in each of Professor Church's three cases, and to show that Δh is

TABLE 1

	V_3	Δh	V_2	$y_{\max}$
Case 2	3.88	84.95	4.35	81.50
Case 3	6.10	25.00	6.23	24.60
Case 4	7.60	10.60	7.56	11.60

greater than his $y_{\max}$ in all except the last case. This, of course, leads to but one conclusion, which is that his values are too small. I do not doubt, however, that they are as accurate as one could figure them by the methods adopted by him, and they are undoubtedly near the truth, but not quite so near in two cases as could have been obtained directly by this equation (23), just written. Of course, this equation is of no value whatever in determining $y_{\max}$ except where $\frac{c}{R}$ is so very large that $y_{\max}$ is not sensibly larger than Δh.

26 By trial in Equation 23, the following values are found for V_3 and Δh for the three cases and I have also listed for comparison Professor Church's values for his V_2 and $y_{\max}$.

Example (case 2):

$$H - CV_1^2 = 80$$
$$V'_0 = 8$$
$$H = 180$$
$$C = 1.00$$
$$640 = 180\ V_3 - V_3^3, \text{ from which by trial } V_3 = 3.88$$
$$\Delta h = (100 - 15.05) = 84.95$$

27 Let us now list the values for $y_{\max}$ as obtained from my Equation 7, putting V_3 (*known before hand*) as the superior limit, and compare them with the values for $y_{\max}$ obtained from Mr. Harza's Equation 20, putting his $V_2 = V_3$ above. He states in Par. 23 that the upward surge is always less than the value given by his Equation

20. Now these are examples of upward surge, and yet it is seen that Equation 20 gives not only smaller values than the true y_{max} but even smaller than Δh, which is itself necessarily at least a little less than the true y_{max} in all cases. It is also seen that the much buffeted Equation 7 gives closer results in these instances than the more exact equation of Mr. Harza's.

TABLE 2

	Equation 20 $y_{max.}$	Equation 7 $y_{max.}$	Δh	Professor Church y_{max}
Case 2	46.60	91.4	85.0	81.5
Case 3	16.00	27.9	25.0	24.6
Case 4	8.75	13.0	10.6	11.6

28 The correct values for y_{max} probably lie between Columns 2 and 3. These computations are all made on an 8 in. slide rule, but are presumably otherwise accurate. The comparison is not made for the purpose of discrediting Mr. Harza's Equation 20, which is a valuable one when judiciously used, just as my own are. I doubt if Mr. Harza himself would make the mistake of using his equation for such unusual cases as 2 and 3, and yet he authorizes its use, to be strictly literal, in Par. 28. I am therefore justified in thus drawing odious comparisons, particularly in view of Mr. Larner's statement (Par. 52) that the consideration of friction sometimes reduces the figured surge. As a matter of fact, it seems to me that friction must always increase the surge (as stated in Par. 23), though oftentimes a negligible amount where $\frac{c}{R}$ is relatively small, in which case Mr. Harza's Equation 20 would probably give excellent results. There is and perhaps can be no hard and fast set of formulae which will accurately cover all cases. One must study the question from all points of view, and work out many examples by arithmetic integration before attempting to use one's judgment. The formulae are all useful to one used to their limitations, and in any event, when all is said and done, one should always check up by means of arithmetic integration before proceeding to build a regulator.

29 In Par. 48, Mr. Larner states that I have "*contended*" that the governor effect is not very important. As I re-read my Par. 24-28 inclusive, and also Par. 56, I wonder if others will draw the same

inference. It is quite conceivable that one might think from the language of Par. 37 and 55, that this important matter had been slighted; I plead guilty to carelessness of expression, but not to intent to deceive. Proceeding exactly as I did in the numerical examples, putting $V_2 = V_{max}$ one incidentally eliminates all governor effect on the surge, and in the case of the timple tank one has some to spare besides; also I wanted to bring out forcibly the point that oftentimes no disastrous results are obtained by substituting what Professor Church terms V'_0 or V_3 for V_2, as illustrated by his case 4 and carefully explained by Mr. Larner himself in Par. 75 and 76.

30 One always knows beforehand the values of V_{max} and V_3 (since y_{max} is selected to be the result of the design). By substituting each in turn if necessary for V_2, one can usually, in a *practical case*, fix the true value of the surge within limits, and thus be sure of being at least safer than by the use of any formula that purports to include all the variable quantities and only partially does so. It should not usually be found necessary to make any material alteration in tank dimensions after checking up by arithmetic integration, as I have repeatedly proved. Therefore, for my own use, I prefer a simple equation like 7, which has the advantage of being fairly accurate for what it purports to show, to a more exact one which only partially does what it claims, always leaving one in some doubt as to the limits between which the true result lies. The following figures will assist in making a little more careful study of the numerical example of Par. 87, in order to help demonstrate the usefulness of Equation 7, when applied with discretion.

31 First, let us solve for V'_0 and V_3; we have

$$\begin{aligned}
V_1 &= 13 \\
V_{max} &= 15 \\
h &= \text{working head for } V_1 \text{ or } V'_0 \\
H &= h + C\,V_1^2 = 216.9 \\
h \text{ for } V_{max} &= 190 \\
190 \times 15 &= 216.9\,V_3 - \tfrac{1}{10}\,V_3^3 \\
V_3 &= 14.55 \\
190 \times 15 &= V'_0 \times 200 \\
V'_0 &= 14.25 \\
\Delta h &= \tfrac{1}{10}\,(\overline{14.55}^2 - \overline{13}^2) = 4.25 < y_{max}
\end{aligned}$$

Equation 7, with $V_2 = V_3$, gives y_{max} = about 7.75

Mr. Harza's 20, with $V_2 = V_3$, gives y_{max} = about 8.25

Equation 7, with $V_2 = V_{max}$, gives y_{max} ± about 10.00

32 None of the values are right, but Mr. Harza's value is without doubt the nearest, though presumably small. If the correct value is about 9, then it is apparent that a tank somewhat smaller than 34 ft. could be used, and therefore my numerical comparison between the simple tank and the differential is rather unfavorable to the former; just how much I cannot say without more work than is possible within the time at present available. Pressure of time made it necessary in the first instance to close my paper almost before I had started any numerical illustrations, and thinking these power computations for different heads elementary, I contented myself with a hurried illustration, believing that any one who went into the subject sufficiently to understand it would have no difficulty in getting some good out of my formulae; for the others, probably no amount of explanation would have sufficed, and the explanation might have been fully as misleading to them as the work I did.

33 The value of R is very sensitive to the magnitude of V_2 and an absolute computation for it is perhaps impossible by any reasonable process; but y_{max} is not so sensitive, and y_{max} is really what one wants to foretell within reasonable limits. It must be remembered also that V_2 is only a guess in the first place, supposedly of sufficient size as compared with V_1 to represent a maximum load change. My study of the vagaries of Equation 7 have not been extensive enough to warrant my writing at any great length. My belief in the superiority of the differential scheme has led me to work with equation 12 for the most part, much to the neglect of Equation 7. I believe, however, that it is a valuable equation for use in connection with Mr. Harza's Equation 20, and probably a combination of the two can be worked out which would be quite accurate for all practical cases.

34 Before closing, I want to say a word about Mr. Larner's statement that for abnormally large loads the simple tank is more "elastic" (see Par. 56, also 62*c*); there is not much in that, practically, because one designs for a certain depth of water at part load in either case, the depth being sufficient to pick up full load. If the load change exceeds that for which one designs, as a maximum, the simple tank will become empty and cease to regulate, just as will the differential form—and at any rate one should fix this maximum load as large as that for which one cares to regulate. Considering two tanks of the same size, the maximum load change under which the simple tank would become empty would be much smaller than that which would empty the differential regulator, and therefore the latter would

be much more "flexible" and "elastic" for all load changes between these two maxima.

35 Another important point in favor of the differential form which I inadvertently omitted to mention, is that since the maximum surge is less a smaller water wheel is required to pick up full load as the head recedes; this works two ways to advantage: the units are less expensive in the first place, and the wheels operate continuously at larger gateage and hence at better normal or average efficiency.

36 There is one important point affecting the accuracy of arithmetic integration when applied to these surge waves, which I have only just touched in Par. 89, and that is the choking head at the entrance to the surge pipe or tank This connection leading out of the conduit to the regulator is necessarily of small area as compared to the tank, and losses of head occur which are neglected in all the formulae and are often overlooked in the arithmetic work. This loss, together with the friction in the riser, in the differential scheme, is not of great importance for small velocity changes, but for a shut-down or a large change of load it may become one of the most important factors. On this account it is evident that Mr. Larner's illustrated examples cannot be strictly correct, although sufficiently so for the purpose intended. I have found it sometimes unsafe to neglect these losses, but like many other things one has to bear them in mind when applying the equations. From the foregoing argument it is apparent that the simple tank is usually not altogether free from differential action, and hence the pressure curve is a double line for large changes of load.

37 Lack of time forbids any useful comments on Mr. Knowles' problems, which present questions altogether too complicated for intelligent discussion in anything like a casual manner; perhaps the method of trial and error by actual experiment is the only way to determine correct solution, and Mr. Knowles is following that line.

38 It has occurred to me that some confusion may result from the foregoing careless use of the expression V'_{max}. This has been intended to refer to the maximum velocity drawn by the wheels, and would be perhaps more properly designated as V'_{max}, The real V_{max}, or the maximum velocity, in the conduit for demanded loads, is always greater than V'_{max}, because acceleration of the long column continues some time after y has reached its maximum, and after V' has begun to decrease. When V_{max} exceeds V_3 by an amount greater than the difference between V and V_1, there is grave danger of a per-

petual wave. For the same values of y_{max} and $V_3 - V_1$, the excess of V_{max} over V'_{max} is less in the differential regulator than in the simple tank. The time when V reaches its maximum value compared with y_{max} is clearly shown in the example of an augmenting wave.

39 In Par. 91 I used the value of V'_{max} as the value for computing the capacity of the tank for a shut-down. Inasmuch as the actual conduit velocity will exceed this value, and since a shut-down may occur at any time, and the formula is not sure to give an outside figure for y_{max}, it is not thought an excessive precaution to use the value of V'_{max}. Mr. Larner did not see any sense in this, however (see his Par. 88), possibly on account of insufficient explanation on my part. I relied on the text to clear up all these points, and attempted to describe the cycle of events with clearness sufficient to preclude any misinterpretation of the mathematics. In the criticisms no mention has been made of the perpetual wave. This, it seems to me, is an important feature to consider. There is nothing in the formulae for the simple tank computations to warn one when approaching the danger limit. I should say, off hand, that when $V'_{max} - V\frac{1}{3} = V_3 - V_1$, there is every likelihood that succeeding waves will be greater than the first one, which would mean a never ceasing change of head and an extremely undesirable condition.

40 For values of $V'_{max} - V_3$, even considerably less than $V_3 - V_1$ the condition of too long life of the wave, even though the wave died out eventually, might well be brought about, making it quite probable that a succeeding new load-change would cause the waves to accumulate disastrously. When $V'_{max} - V_3 = V_3 - V_1$, it can be easily shown that

$$y_{max} = h - \frac{V_0' h}{2V_3 - V_1} \qquad [24]$$

where h is the working head for V_1.

41 Without sufficient study to warrant a decisive statement, I would at least suggest that the value of R be always made less than half that which would give this value of y_{max}. If one has the patience one can try out a number of cases by arithmetic integration, where $y_{max}h$ as values some less than that given above and see what eventually becomes of the wave. This ought to be done. It looks as though this expression would be at least a fairly correct index as to the danger limit, and it is easily applied, because V'_0, V_1 and V_3 may always be easily found as previously pointed out.

42 Until something better is developed, this value of R may

be taken as indicating the region of the danger limit. It is at least a better expression of the facts than the empirical rule which I previously offered in Par. 57. V'_{max} is, to be sure, not as large as V_{max}, but on the other hand it is probably always too large for the correct V_2 in Equation 7. It is possible that these two errors will tend to offset each other sufficiently to indicate with some accuracy the critical value of R in a practical working case.

43 Mr. Larner also at times uses the expression V_{max} for the maximum draft velocity. The penstock velocity does not reach its maximum in the first quarter cycle, and hence the only V_{max} which really exists in his theoretical studies is V'_{max}, and there should be no confusion to a thinking man. The equations are not concerned with any velocities occurring later in the cycle than the end of the first quarter.

44 Now the V_2 which Mr. Larner has introduced into his formulae not only does not occur in the first quarter, but theoretically it never occurs in a finite time. It is the ultimate value of V' after all vibrations have ceased. It is a strain upon the imagination to involve this quantity in the computations for the first quarter cycle. It can be dragged in without error, to be sure, just as Mr. Larner has ingeniously shown, but that it is misleading and unnecessary is well brought out by the fact that in working out the curves herewith submitted I never used this value at all.

45 I had no occasion even to know what it was, for the very sufficient reason that it does not exist during the first quarter cycle which I was studying. A casual reference to Par. 6 will indicate the normal and rational way to begin a surge study. V_1 has to be known. V'_0, a function of the load change, is the same as my V_2 when the latter is assumed constant for the sake of integration. V_3, or Mr. Larner's V_2, never even appears as such during the whole arithmetic integration—and it is rather plain therefore that all of his discussion about the effect of the friction upon V', etc., etc., which results directly from appropriating this V_3 and mixing it up needlessly in his equations might as well have been omitted.

46 The introduction of V_3 involves nothing whatever but an elementary power computation, and it has no proper place in the theoretical work. Any one who chooses may compute it easily, for any rational purpose. I often do so for the sake of substituting it for V_2 in Equation 7, not because it has any real theoretical place there, but because I have found by experience that this value represents a convenient working mean between V'_{max} and V'_0, which usually gives fair results when substituted for the upper limit in Equation 7.

47 The value for y_{max} thus found is usually low, but close in a practical working case, as Mr. Harza's comparisons show. As before pointed out, one may also get a value of y_{max} greater than the true value, by putting $V_2 = V'_{max}$.

48 It is interesting to note, in view of the importance assigned to Mr. Larner's V_2, that in all his elaborate arithmetical studies for Case 4, represented graphically, this value does not even appear; and in fact, cannot appear, theoretically, in any finite time. It would, therefore be rather a laborious operation for him to prove arithmetically that he needed this value in order to proceed with his work.

49 Mr. Larner leads one to infer, in Par. 88, that Mr. Harza intends his V_2 to mean V_3 invariably. This cannot be the case, however, as a glance at his Equations 13 and 14 would indicate. In Equation 13 the value of the first V_2 was intended to be V'_0, or possibly V_3, by a stretch of the imagination. Either value would apply. It seems clear, however, that the value intended in Equation 14 for V_2 is V'_{max} because, in the time $\frac{T'}{2}$ of a quarter cycle, the velocity in the penstock varies from V_1 to V'_{max}. His work is nevertheless very instructive to me, and I realize that without the admixture of considerable judgment none of these equations can be used. Mr. Larner looks to hand-book simplicity as his ideal, but I fear that this desirable condition will never be reached. My chief criticism of Mr. Harza's work is its claim to greater accuracy than the facts warrant.

50 In the light of Mr. Larner's criticism of my work, Mr. Harza should be able to do as I have now attempted, namely: to show his real intentions where insufficiency of explanation leaves many things in doubt to any but a very careful student. Mr. Larner's attention to detail, and his insistence upon the accurate use of symbols, has opened up the whole subject to the light, and made it compulsory for me, in justification of myself, to clear up many points.

51 I think it now behooves Mr. Harza to do likewise as soon as possible. To my mind, his Equation 13 should strictly read,

$$E_w = A\,V_0'\,\frac{T'}{2}\,w\,(H - C\,V_1^2)$$

Equation 14 should read

$$E_a = \frac{w}{2g}\,A\,L\,(V'^2_{max} - V_1^2)$$

and Equation 10 cannot be expressed exactly, because it assumes a

constant V_2, just as I have done, and whether it is better to assign a value of V_3 or V'_{max} is hard to tell without much study.

52 It might be argued that the presence of V_3 in the formula is essential in order to predetermine the capacity of the water wheels after the surge. There would seem to be nothing in this, however, for the greatest tax upon the wheel is when it has to hold up full load under a head of $h - y_{max}$ in which V_3 again does not appear.

53 Several errors have crept into my paper in spite of considerable care, and I have attempted to have them all weeded out in the final printing. An important one occurs in Par. 85, where I inadvertently used the phrase "change in hydraulic gradient" instead of "change in water level," or, strictly, "change in pressure at the turbines."

54 A word in reference to Mr. Larner's laborious work of arithmetic integration will conclude my remarks. Not having the time at my disposal to check over this work, I must be content with a statement of some general conclusions. In Example 1 I note an exact agreement between the tabulated values of V_2 and V'_{max}. Inasmuch as this is theoretically impossible, and Mr. Larner has always before taken V_2 as his starting-point, one is led to question the accuracy of this example.

55 In Example 2, V_2 has a larger value than V'_{max}. This is *a fortiori* an impossible condition, because the change in tank level due to the change in gradient alone is larger than the value given for y_{max}. I have previously called this Δh. If V_2 is 14.80, then Δh must be about 15 ft., whereas y_{max} is given as 14.84. It is evident that the true value of y_{max} must be greater than Δh or greater than 15. Even if it were only just equal to 15, it would play havoc with Mr. Larner's percentages of excellence which are, as will be shown, a little misleading. A correction, for example, along the lines just indicated, would probably reverse the burden of error from the result obtained by Equation 7 to that derived from the use of Mr. Harza's equation. It appears, however, that for the most part, the tabulated results are sufficiently accurate and they show very clearly the obvious fact that Equation 7 with $V_2 = V'_{max}$ is an excellent one for practical use, because it *always gives values on the safe side*, and so near the truth that any further so-called refinement by uncertain processes is not essential. The values given by Mr. Harza's equation, although much closer on the average than my own, are not any more useful because they are too often *unsafe*, and one never knows just how much.

56 Omitting Examples 1 and 2, and also No. 12, which is practi-

cally an impossible case, I offer a table (Table 3) made up from Mr. Larner's figures, as illustrating about the degree of error in the use of Equation 7. The assumed load change is only a refined guess at best. The comparative values here given indicate the percentage of load change for which one actually provides by Equation 7, as compared with the percentage of load change intended to apply. In other words, a surge tank as designed by Equation 7 will take care of a load change, according to column 2, if designed for the corresponding load change indicated, for the various examples, in Column 1. I am indebted to Mr. Larner for his exhaustive work whereby I am enabled thus concisely to express the real error.

TABLE 3

Example No.	Per cent Load Change as estimated.	Approximate Per cent Load Change Provided for by Equation 7.	Error.
3	20	20.7	.7
4	15	16.1	1.1
5	10	10.9	.9
6	15	16.2	1.2
7	10	10.7	.7
8	15	15.8	.8
9	10	10.5	.5
10	10	11.7	1.7
11	13	13.8	.8
13	6	6.8	.8
14	15.5	17.9	2.4
15	12	13.8	1.8
Averages...........	12.6	13.7	1.1

57 The figures are exact only in so far as Mr. Larner's percentages of error in y_{max} are correct and they are made up on the further assumption that the proportionate increase in load change is the same as the proportionate error in y_{max}, which is only a rough approximation within narrow limits. Column 3 shows the practical error encountered in the use of Equation 7, expressed in precentage of part load, and may readily be compared with the total assumed change in each case. The futility of further refinement of these values is clearly brought out by the fact that it is imperative when one uses the simple tank, to work out by arithmetical integration at least *one and one-quarter* cycles in order to be assured that the pressure wave will not *live too long.* I have found this condition to exist where it could not have been foreseen by any process of reasoning available to me.

58 Mr. Larner's method of using Equation 7 will perhaps always give closer results than the method I have adopted as a *safe course*; it naturally will, at any rate, for the set of cases which he has carefully worked out. One should, however, always bear in mind, that if one adopts anything less than unity for the value of Mr. Larner's K, there is at least a good chance that the resulting design will provide for less load change than that intended. The same thing is true in his use of Mr. Harza's equation, only rather more emphatically so. In future, for my own purposes, I believe I shall generally use Mr. Harza's equation when a close approximation is desired; although it is just as essential to have recourse to Equation 7 as well in order to determine the upper limit of a safe value. If only one equation be used the preference ought to be given to the latter. One may state with considerable precision, and with danger of misleading, that Equation 7 provides for 10 to 20 per cent greater load change than that assumed in the premises. This error may be materially reduced if considered worth while, by the exercise of a little judgment, which may be greatly assisted by reference to Mr. Larner's excellent work.

59 From a practical point of view, another reasonable way of regarding the error encountered in the use of Equation 7, is through an inspection of the algebraic expression for porportionate load change, which is,

$$1 - \frac{h V_1}{(h - y_{\max}) V_{\max}}$$

where h is the working head for the velocity V_1. $V_{\max}$ is an important item for consideration as well as $Y_{\max}$, and for the same assumed range of $V_{\max} - V_1$ and for a value of $Y_{\max}$ only a very small part of h, say, 5 per cent as it should be in a practical case, errors of even 15 per cent in the computed value of $Y_{\max}$ would not ordinarily mean as much as 1 in the figured percentage of load change. It is never necessary to make errors nearly so great as 15 per cent if one has gone into the subject sufficiently to be qualified to use the equation at all. If one does not foresee and bear in mind the obvious fact that a substitution of $V_{\max}$ for V_2 in Equation 7 will give a value of R too small, one may naturally multiply errors unreasonably by persistently increasing $V_{\max}$ for a fixed V^1_0, in order to make it agree with Y which is itself already too large; such a course is inexcusable. A tank designed on the lines of the foregoing study would allow a

trifle excess depth which would permit, on extraordinary occasion, a useful increase in the value assumed for V_{max} and incidentally allow Y_{max} to attain its assigned value; this would take care of slightly extraordinary load change, provision for which would be inexpensive as compared with the somewhat unintentional factor of safety furnished.

ACCESSIONS TO THE LIBRARY

BOOKS

Annual Report of the Chief of the Bureau of Construction and Repair to the Secretary of the Navy, 1887. *Government, Washington, 1887.*

Annual Report of the New York State Museum, 1906. Vol. 1, 2, 3, 5, *State Education Department, Albany, N.Y., 1908.* Gift.

American Foundry Practice. By T. D. West. *J. Wiley and Sons, New York, 1882.* Gift.

Bulletin of the Geological Institution of the University of Upsala, Vol. 8, No. 15–16, 1906–1907. *Upsala, 1908.* Gift of University of Upsala.

Directory of Living Graduates of Yale University, 1906. *Tuttle, Morehouse and Taylor, New Haven, 1906.* Gift.

Report of the Commissioner of Education for Year ended June 30, 1907. Vol. 1, *Government, Washington, 1908.*

Brakes from Freight Cars, both from an Economic and an Operative Point of View. By W. V. Turner and S. W. Dudley. Gift of Canadian Railway Club.

Electrical Influence Machines. By John Gray. *Whittaker & Co., and Van Nostrand, London, New York, 1890.* Gift.

Electrification of the St. Clair Tunnel (Grand Trunk Railway System). By. F. A. Sager. *Grand Trunk Roilway System, Montreal, 1908.* Gift.

Incandescent Electric Lights. By C. Th. du Moncel and W. H. Preece. Edition 2. *D. Van Nostrand, New York, 1882.* Gift.

Indicator Diagrams, Engine and Boiler Testing. By Charles Day. *Technical Publishing Co., Manchester, 1895.* Gift.

Indicator Handbook: A Practical Manual for Engineers By C. N Pickworth. Part 1. *Emmott & Co., Manchester, 1898.* Gift.

Injurious Effect of a Blue Heat on Steel and Iron. *Washington, Government, 1887.* Naval Professional Paper No. 21. 1887. Gift.

Lecons sur les Moteurs a Gaz et a Pétrole. By L. Marchis. *Gauthier Villars, Paris, 1901.*

Main Sewerage and Sewage Disposal. By T. A. Murray. *Toronto, Canadian Engineers.* Gift of Publisher.

Mechanic's Workshop Handybook. By P. N. Hasluck. *Crosby, Lockwood & Son, London, 1888.* Gift.

Physical Problems and Their Solutions. By A. Bourgougnon. *D. Van Nostrand Co., New York, 1897.* Gift.

Primer of the Calculus. By E. S. Gould. *D. Van Nostrand Co., New York, 1896.* Gift.

Recent Improvements in the Steam Engine. By John Bourne. *Longman, Green, Longman, Roberts & Green, London, 1865.* Gift.

Steam Economy as Illustrated by the Use of the Steam Engine Indicator, Practically Considered, Being a Reflex of Actual Tests. By A. Wilkinson. *Philadelphia, 1882.* Gift.

Symposium on Mathematics for Engineering Students, Being the Proceedings of the Joint Sessions of the Chicago Section of the American Mathematical Society and Section A, Mathematics, and Section D, Mechanical Science and Engineering, of American Association for Advancement of Science, held at University of Chicago, Dec. 30 and 31, 1907. Reprint. Gift.

EXCHANGES

Annual Report of the Commissioner of Patents, 1907. *Government, Washington, 1908.*

Geology and Water Resources of a Portion of South-Central Oregon. By G. A. Waring. *Government, Washington, 1908.* U. S. Geological Survey Water Supply Paper No. 220.

Ground Waters and Irrigation Enterprises in the Foothill Belt, Southern California. By W. C. Mendenhall. *Government, Washington, 1908.* U. S. Geological Survey Water Supply Paper No. 219.

Report of the Proceedings of the Forty-second Annual Convention of the Master Car Builders' Association Held at Atlantic City, N. J., June, 17–19, 1908. *The H. O. Shepard Co., Chicago, 1908.* (Exchange)

Transactions of the Manchester Association of Engineers, Session 1907–1908. *Herald & Walker, Manchester, 1908.*

CATALOGUES

The Flinn Steam Trap. 1908.

General Electric Company, Schenectady, N. Y. Multiple Luminous Arc Lamps, Sept. 1908. Curve Drawing Instruments for Alternating and Direct Current Circuits. Oct. 1908.

The M. W. Kellogg Co., 50 Church St., New York. Piping and Chimneys. 1908.

National Machinery Company, Tiffin, O. National Interchangeable Die.

Northern Electrical Manufacturing Co., Madison, Wis. Northern Type S Motors. Bulletin 59.

Westinghouse Electric and Manufacturing Co., Pittsburg, Pa. Direct Current Generators, Type S and R (Circular No. 1156). Direct Current Motors Type EM (Circular No. 1138). Polyphase Induction Motors (Circular No. 1118). Westinghouse Type S Distributing Transformers (Circular No. 1157).

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

039 Young man wanted to serve as assistant in the mechanical engineering department of a large technical school. Must be familiar with steam power machinery. Position must be filled immediately. Location, New York.

040 Energetic and capable engineer to build and operate plant; to take complete charge of power house, both electric and ice-making and be accountable for costs of production. Must invest one or two thousand dollars or more. Living quarters in conjunction with plant. Service to begin not later than February 1, 1909. Salary not to exceed $100. Location, Colorado.

041 An engineering company in New York wishes to engage young technically-educated engineer as assistant inspector and tester. One with practical as well as theoretical knowledge of isolated plants preferred. Apply by letter, stating qualifications fully.

MEN AVAILABLE

185 Member, with thorough business training, up-to-date factory manager; good executive and organizer; competent in manufacturing medium and light machinery or in purchasing department; fully qualified to fill position of responsibility. Patentee many devices. Willing to go abroad.

186 Member, familiar with gas engine and producer business, in touch with a large number of Eastern prospects, will consider equitable proposal to represent a reliable company or companies building gas engines and gas producers or both.

187 Junior, technical graduate, married, age 32; 12 years experience consisting of shop work, drafting, erecting and operating large steam and gas engines; desires to change

188 Member who has given his attention to the design of special machinery and tools for manufacturing purposes, wishes a position in this line, or as assistant superintendent.

189 Electrical engineer and superintendent of construction, 8 years in charge of design, construction and operation of electrical refrigeration and ice-making plants, responsible charge. Experience covers period of 18 years.

190 Member, Stevens graduate, at present holding responsible position with large concern, desires to make change. 18 years experience, general manufacturing and foundry work, 5 years power and manufacturing plant construction, including design and equipment. Capable of filling position of manager, general superintendent, or chief engineer in charge of construction work, repair and maintenance of plant and equipment. Chicago or New York preferred. Salary $8000 to $10,000 or its equivalent.

191 Junior, experienced business and sales manager. Willing to go abroad.

192 Junior, American, married, 3½ years general design, fabrication and erection, in Mexico, speaks Spanish, German, Russian, and a little French, would like to make the acquaintance of parties having European or Latin-American connections, with view to present or future engagement.

193 Member, at present assistant works manager of one of the large maufacturing establishments of the country, wishes to make a change. Consulting experience, familiar with power plant and steam engine design; served for some time on the teaching staff of an engineering college.

194 Inspector of construction on water works, or mill work: also extensive practical experience in management of large undertakings. and upbuilding of one of the foremost American textile factories. Railroad experience.

195 British manufacture of American patents; member, technical graduate with 12 years varied and practical experience, especially mining machinery and contractor's plants, 5 years in England managing European branch of American house. Now in America; would like to hear from American owners of British patents expecting to start manufacture in England under requirements of new British Patents Act or desirous of placing British rights in the hands of responsible manufacturers upon royalty or other basis.

196 Member, open for engagement, specialty supervision in hydraulic engineering as manager and superintendent. Extensive experience in construction of pumping machinery, designing and equipment of manufacturing plants for economical production.

197 Associate member, 5 years experience as consulting engineer in Mexico, speaks Spanish fluently, desires engagement, preferably South America or Mexico.

198 Sales manager and engineer, member, open for engagement after January 1, 1909. Established in New York; knows manufacturing and selling, competent to lay out and estimate work. Broad experience through travel for special machinery and plant equipments. Manufacturers and bank references.

199 Member, technical graduate, 20 years experience, 10 years in charge of design, construction and maintenance industrial and steam plants, crushing, hoisting, conveying and transmission machinery; reinforced concrete.

200 Junior member, technical graduate in mechanical engineering, married' ten years varied experience, including shop work, drafting and as superintendent of construction of buildings and complete steam and electrical plant, the erection and testing of steam engines. At present employed as Chief Engineer of extensive plant. Desires position in East as assistant manager or superintendent of industrial concern or with consulting engineer.

201 Superintendent or manager experienced in the manufacturing machine shop, gray iron and brass foundries producing large output of good quality.

202 Associate, technical graduate with experience in engineering laboratory, drafting room, miscellaneous work and special machinery design, experimental and testing work, wishes to connect with consulting or contracting engineer in Chicago. Has had charge of work. Can invest small sum if mutually agreeable.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ANCONA, John F. (Junior, 1904), Ch. Draftsman, Eastman Kodak Co., Kodak Park Wks., and *for mail,* 2 Magee Ave., Rochester, N. Y.

ARNOLD, George (1904), 1763 E. 63d St., Cleveland, O.

BAKER, Chalice Whitmore (1905), Great Northern Power Co., Fond du Lac, Minn.

BIGELOW, Charles H. (1904), with Chas. T. Main, Mill Engr., 45 Mills St., Boston, Mass., and *for mail,* 237 Duncan Ave., Jersey City, N. J.

BIRDSEY, Charles Robt. (Associate, 1907), Ch. Engr., U. S. Gypsum Co., 200 Monroe St., and *for mail,* 934 Harrison St., Chicago, Ill.

BLAKE, Clinton F. (1901), 1494 Park Ave., Chicago, Ill.

BLISS, Collins P. (1903), Prof. Mech. Engrg., N. Y. Univ., and Bliss-Griffiths Constr. Co., 225 5th Ave., and *for mail,* 2206 Andrews Ave., Univ. Heights, New York, N. Y.

BOLLES, Frank G. (Associate, 1901), Allis-Chalmers Co., Milwaukee, and *for mail,* Franksville, Wis.

BOURQUIN, James T. (Junior, 1907), Inspr. for Purchasing Dept., Chalmers Detroit Motor Co., Detroit, Mich., and *for mail,* P. O. Box 42, Muskegon, Mich.

BRAUN, Carl F. (Junior, 1907), Engr. Standard Elec. Wks., 121 New Montgomery St., and 118 Gough St., San Francisco, Cal.

BUCHANAN, A. W. (1899; 1904), Am. Conduit Co., Los Angeles, Cal., and *for mail,* 2340 Cherry St., Denver, Colo.

BUCKLEY, John F. (1906), Mech. Engr., 3228 E. 11th St., Kansas City, Mo.

BULKLEY, Henry W. (1885), Mech. Engr. and Mfr., 141 Broadway, New York, N. Y., and Orange, and *for mail,* 158 Harrison St., East Orange, N. J.

CROLL, A. Gilbert (Associate, 1901), Supt., Atlas Portland Cement Co., Northampton, and *for mail,* 530 N. 6th St., Allentown, Pa.

DAVOL, George K. (1904), Mech. Engr., 503 Market St., San Francisco, Cal.

DIETZ, Carl E. (Junior, 1903), Cons. Engr., 306 Main St., Melrose, Mass.

DONNELLY, Wm. T. (1903), Cons. Engr., 135 Broadway, New York, and *for mail,* 808 E. 18th St., Brooklyn, N. Y.

DRAPER, Wm. L. (1899), Turbine Dept., Genl. Elec. Co., 84 State St., and *for mail,* 8 St. Botolph St., Boston, Mass.

FAILE, E. Hall (Junior, 1907), Mech. Engr., City Investing Co., 165 Broadway, and *for mail,* The Dakota, 1 W. 72d St., New York, N. Y.

FEICHT, Edward R. (Junior, 1907), Engr., Water Light and Gas Co., and *for mail,* 118 1st Ave., E. Hutchinson, Kan.

FLANNERY, John M. (1907), Asst. to Estimating Engr., The Solvay Process Co., and *for mail,* 1628 W. Genesee St., Syracuse, N. Y.

FOLGER-OSBORNE, G. F. (1903), care of Messrs. Cox & Co., Bankers, Fort Bombay, India.

FUCHS, Ernesto (1906), Engr. and Arch., Box 334, and 1402 Calle de Hidalgo, Guadalajaro, Mexico.

GARRETT, John Anthony (Junior, 1907), Gas and Mech. Engr., Fairbanks, Morse & Co., 423–9 E. 3d St., and 1554 Winfield St., Los Angeles, Cal.

GILLET, Louis Allston (Junior, 1901), Fishkill-on-Hudson, N. Y.

GREENLEAF, Geo. Edward (1892), Mech. Engr., Niles-Bement-Pond Co., Plainfield, N. J.

GUMP, Walter B. (Junior, 1902), Mech. and Elec. Engr., 2510 Juliet Ave., Los Angeles, Cal.

HENES, Louis G. (Junior, 1903), Mech. Engr., 128 E. 93d St., New York, N. Y.

HENRY, George J., Jr. (1901), Ch. Engr., The Pelton Water Wheel Co., 19th and Harrison Sts., and 3999 Clay St., San Francisco, Cal.

HIRSHEIMER, Harry Julius (1892; Associate, 1904), V. P. La Crosse Plow Co., and *for mail,* 131 S. 15th St., La Crosse, Wis.

JACKSON, Percy (Junior, 1904), P. O. Box 193, and 826 Orange St., Macon, Ga.

JACKSON, Walter W. (1902), Engr. of Water Supply, City Hall, and 284 S. Champion Ave., Columbus, O.

JONES, Clement R. (1898; 1901), Prof. Mech. Engrg., West Virginia Univ., and 262 McLane Ave., Morgantown, W. Va.

JONES, John Emyln (1907), Jones & McKee, Cons. Engrs., Singer Bldg., and 403 W. 115th St., New York, N. Y.

KAUFMAN, Emanuel (Associate, 1902), Mgr., Kaufman Steel Co., 516 Frick Bldg., and 5815 Fifth Ave., Pittsburg, Pa.

KEELY, Royal R. (1901; 1907), Cons. Engr., Kelowna, British Columbia, Canada.

KEITH, Thomas M. (Junior, 1905), Ch. Engr., Link Chain Belt Co., 52 Dey St., New York, and 414 McDonough St., Brooklyn, N. Y.

KENT, Edmund (1887), care of Am. Soc. of Mech. Engrs., 29 W. 29th St., New York, N. Y.

LANE, Frederick (1906), Supt., Jenkins Bros., Ltd , St. Remi St., Montreal, and 1 Benton Ave., Westmount, Quebec, Canada.

LYLE, Joel Irvine (1906), Mgr., Carrier Air Conditioning Co., 39 Cortlandt St., New York, N. Y., and 1200 W. 7th St., Plainfield, N. J.

McLAUGHLIN, James (1901), Pres., McLaughlin Bros., 915 Bolton St., Baltimore, Md., and 521 St. James St., and *for mail,* The Art Club, Philadelphia, Pa.

MacGILL, Chas. Frederick (1896), Mgr., Lyon Metallic Mfg. Co., and *for mail,* P. O. Box 134, Aurora, Ill.

MARTELL, Louis H. (1906), Specialist in Metal Packings, Elyria, O.

MOORE, Harold T. (Associate, 1907), Production Engr., Bridgeport Brass Co., and *for mail,* University Club, Bridgeport, Conn

MUNBY, Ernest J. (1906), 237 W. 76th St., New York, N. Y.

RAQUE, Philip E. (1891), Cons. Engr., 15 Broadway, New York, N. Y., and 82 Booream Ave , Jersey City, N. J.

REID, Robert C. (1907), Hewitt Motor Co., 10 E. 31st St., New York, N. Y., and *for mail,* Englewood, N. J.

ROYSE, Daniel (1891; 1904), care of W. V. S. Thorne, 120 Broadway, New York, N. Y.

SALDANA, Eduardo E. (Associate, 1903), Mech. Engr. and Ch. Engr., Central "Carmen," Vega, Alta, and *for mail*, 89 Allen St., San Juan, also, Santurce, Porto Rico.

SCHERR, Frederick, Jr. (Associate, 1907), Asst. Engr., Fajardo Sugar Co., Fajardo, Porto Rico.

SMITH, Edward Jos. (1904), Mech. Engr., The Pusey & Jones Co., Wilmington, Del., and *for mail*, 102 S. 13th St., Allentown, Pa.

SOPER, Ellis Clerk (Junior, 1905), Pres., The Soper Co., 1110–11 Ford Bldg., and 54 Blaine Ave., Detroit, Mich.

SPEER, Chas. Henry (Associate, 1907), Carr & Speer, Metallurgical and Mech. Engrs., 120 Liberty St., New York, N. Y.

STEENSTRUP, Peter S. (1906), Secy., Hyatt Roller Bearing Co., 427 Middlesex St., Harrison, N. J., and *for mail*, 75 Calvert Ave., Detroit, Mich.

STEVENS, Alfred H. (1898; 1903), Engr. and Contr., 149 Broadway, New York, and *for mail*, 806 Washington Ave., Brooklyn, N. Y.

TERRY, Charles Dutton (1902; 1908), Supt., Mills Depts., Natl. Tube Co., Kewanee Wks., and *for mail*, 334 W. Prospect St., Kewanee, Ill.

VANDEMOER, John (Associate, 1904), Mazapel Copper Co., Apartado 64, Saltillo, Coahuila, Mexico.

WEBB, John Burkitt (1882), Prof. of Mathematics and Mechanics, Cons. Engr., Hoboken, and Glen Ridge, N. J.

WHITEFORD, James F. (1908), Betterment Supervisor, A. T. & S. F. R. R., and *for mail*, 281 I St., San Bernardino, Cal.

WISEWELL, Francis Henry, Jr. (Junior, 1905), Internatl. Heater Co., Utica, N. Y.

WOOD, Albert Carroll (1894; 1904), Cons. Mech. Engr., Pennsylvania Bldg., Cor. 15th and Chestnut Sts., and 1317 Spruce St., Philadelphia, Pa.

NEW MEMBERS

ADAMS, Kilburn E. (Junior, 1908), Mech. Engr., and Asst. Mgr., Wm. Underwood Co., 52 Fulton St., Boston, Mass.

ANGSTROM, Carl J. (1908), Designing Engr., Am. Steel and Wire Co., 94 Grove St., and 11 Harvard St., Worcester, Mass.

ARD, Charles Edgar (1908), Prof. of Physics and Elec. Engrg., Miss. Agricultural and Mech. College, Agricultural College, Miss.

ARMSTRONG, Frank Hall (1908), Mech. Engr., Pa. Iron Mining Co., Republic Iron Co., Vulcan, Mich.

ASHTON, Walter S. (1908), Ch. Engr., St. Louis Brewing Assn , and *for mail*, 1727 Cora Ave., St. Louis, Mo.

ATWOOD, William S. (1908), Mech. Engr., Dominion Car and Fdy. Co., Ltd., and 225 Metcalf Ave., Montreal, Canada.

AUTENRIETH, George C. (Junior, 1908), Instr Descriptive Geometry and Drawing, College of the City of N. Y., and *for mail*, 1628 St. Peters Ave., Westchester, New York, N. Y.

BARNES, William O. (1908), Engr.-in-Ch., Ross Rifle Co., and *for mail*, 88 Lachevrotiere St., Quebec, Canada.

BARTLETT, Charles H. (1908), Constr. Engr., Stone & Webster Engrg. Corp , Boston, and *for mail*, 8 Copley St., Winchester, Mass.

BAXTER, Burke Morgan (Junior, 1908), 6823 Aetna Road, S. E., Cleveland, O.
BEECHER, Henry Ward (Junior, 1908), Chas. C. Moore & Co., 618 Mutual Life Bldg., Seattle, Wash.
BROWN, Howard Hayes (Junior, 1908), Editor, International Marine Engrg., 17 Battery Pl., New York, N. Y.
BROWN, Richard P. (Junior, 1908), Mfr. Scientific Instruments, Edward Brown & Son, 311 Walnut St., Philadelphia, Pa.
CHACE, William W. (1908), Mech. Engr., The Cleveland Twist Drill Co., and *for mail,* 40 Elberon Ave., East Cleveland, O.
CHARAVAY, Marius A. (Junior, 1908) Instr. Experimental Engrg., Stevens Inst. of Tech., Hoboken, and 225 Palisade Ave., Jersey City, N. J.
COLEMAN, William W. (1908), Wks. Mgr., The Bucyrus Co., S. Milwaukee, and 337 Prospect Ave., Milwaukee, Wis.
COMSTOCK, Charles W. (1908), Cons. Engr., City of Denver, Boston, Bldg., Denver, Colo.
CONNET, Frederick N. (1908), Sales Mgr., Builders Iron Fdy., 9 Codding St., Providence, R. I.
CRAWLEY, George E. (Junior, 1908), 557 W. 124th St., New York, N. Y.
CRO ELL, William Jas. Jr. (Junior, 1908), Gas and Test Engr., Am. Iron and Steel Co., and 128 E. Cumberland St., Lebanon, Pa.
DAMON, John H. (Associate, 1908), M. M. and Expert on Rope Transmission, Plymouth Cordage Co., and 258 Court St., Plymouth, Mass.
DURFEE, Walter C. (Junior, 1908), Experimental Engr., Walworth Mfg. Co., Boston, and 81 Sedgwick St., Jamaica Plain, Mass.
EATON, Henry Chas. (Associate, 1908), Foreman, Engrg. Dept., Waltham Watch Co., Waltham, Mass.
EMSWILER, John Edward (Junior, 1908), Instr. Mech. Engrg., Univ. of Mich., Ann Arbor, Mich.
EYERMANN, Peter (1908), Ch. Engr., Du Bois Iron Wks., Du Bois, Pa.
FERMIER, Emile J. (1908), Prof. of Mech. Engrg., Agricultural and Mech. College of Texas, College Sta., Texas.
FILLINGHAM, Myles Percy (1908), Cons. and Contr. Engr., 2 Rector St., New York, N. Y.
FLANDERS, Ralph E. (Associate, 1908), Assoc. Editor, Machinery, and *for mail,* 123 W. 82d St., New York, N. Y.
FOSTER, William B. (1908), Supt. and Ch. Engr., Foster Bros. Mfg. Co., and 79 Oneida St., Utica, N. Y.
FROST, Edward J. (1908), Pres., Frost Gear & Mch Co., 301 Clinton St., Jackson, Mich.
GILMAN, Francis L. (1908), Shop Supt., Western Elec. Co , 463 West St., New York, N. Y.
HALLENBECK, George E. (1908), Genl. Supt., Baker Bros., Post St., and Westlake Ave., and 2403 Lawrence Ave., Toledo, O.
HODGINS, George S. (1908), Managing Editor, Railway and Loco. Engrg., 114 Liberty St., New York, N. Y.
HARTWELL, Harry (1908), Cons. Engr., Sanderson & Porter, 52 William St., and 975 Park Ave., New York, N. Y.
HILL, Reuben (1908), Genl. Supt., Tiffany Studios Factory, Corona, L. I., N. Y.
HOLL, Charles L. (Junior, 1908), Allis-Chalmers Co., and *for mail.* 3207 Malden St., Chicago, Ill.

HUSSEY, Charles W. (Junior, 1908), 31 Landscape Ave., Yonkers, N. Y.

HUTTON, Mancius S. (Junior, 1908), Secy. and Demonstrator. Am. Museum of Safety Devices, and *for m il*, 257 W. 86th St., New York, N. Y.

JEALOUS, Arthur R. (Junior, 1908), Draftsman, Am. Woolen Co., and *for mail*, 101 Franklin St., Lawrence, Mass.

KENNEDY, William A. (Junior, 1908), Instr., Mech. Drawing, Brown Univ., Providence, R. I.

KETCHUM, Samuel (Associate, 1908), Ch. Draftsman, M. H. Treadwell Co., 140 Cedar St., New York, N. Y.

LAPAT, Leopold (Junior, 1908), Tester in Centrifugal Dept., The Henry Worthington Hydraulic Wks., Harrison, and *for mail*, 249 Godwin St., Paterson, N. J.

LATHAM, Harry M. (1908), Mech. Engr., Am. Steel and Wire Co., and *for mail*, 94 Grove St., Worcester, Mass.

LATON, Thomas J. (Junior, 1908), Instr. in Drawing and Mech. Engrg., New Hampshire College, and *for mail*, Box 155, Durham, N. H.

LEES, John Walter (1908), Genl. Supt. Inland Steel Co., Indiana Harbor, Ind.

LINDBERG, Fritz A. (Associate, 1908), Asst. Engr., Geo. M. Brill, 1134 Marquette Bldg., ad 5832 Indiana Ave., Chicago, Ill.

LOTHRUP, Marcus T. (Junior, 1908), Halcomb Steel Co., Syracuse, N. Y.

McBRIDE, Thomas C. (1908), Sales Mgr., International Steam Pump Co., and *for mail*, 724 Arch St., Philadelphia, Pa.

McFARLAN, Edward (Junior, 1908), 360 Jefferson Ave., Brooklyn, N. Y.

MANTON, Arthur W. (1908), Engr. in Charge East River Tunnel, S. Pearson & Son, Long Island City, L. I., N. Y.

MERKT, Gustav Adolph (Associate, 1908), Designing Engr., Am. Steel and Wire Co., and *for mail*, 3 Pelham St., Worcester, Mass.

MOORE, Edwin A. (1908), Pres., Am. Coke and Gas Constr. Co., 2d and Cherry Sts., Camden, N. J.

MUHLFELD, John E. (1908), Genl. Supt. M. P., Baltimore and Ohio R. R., and *for mail*, 2214 Enton Pl., Baltimore, Md.

NIBECKER, Karl (Junior, 1908), Instr. Mech. Engrg. Univ. of Penn., Philadelphia, and *for mail*, Glen Mills, Del. Co., Pa.

NORDBERG, Carl Victor (1908), Rep. Nordberg Mfg., Co. and *for mail*, 52 E. Granite St., Butte, Mont.

PAPE, James Otto (Junior, 1908), Pittsburg Valve and Fittings Co., Barberton, O.

PEARSALL, Gilbert H. (Associate, 1908), Genl. Mgr. of Sales, Jos. T. Ryerson & Son, 18 Milwaukee Ave., Chicago, Ill.

PERKS, George W. (1908), Supt., Superior Drill Co., Springfield, O.

PORTER, John A. (1908), Genl. Supt., Bibb Mfg. Co.'s Mills and Shops, and *for mail*, P. O. Box 75, Macon, Ga.

RIPSCH, Charles Wm. (Junior, 1908), Mech. Engr., 113 Hawthorne St., Dayton, O.

RITCHIE, Francis P. (Associate, 1908), Shop Supt., Northern Elec. and Mfg. Co., Notre Dame and Guy Sts., Montreal, Quebec, Canada.

ROBBINS, John L. (Junior, 1908), Asst. Engr., Robbins, Gamwell & Co., Pittsfield, Mass.

SIBLEY, Frederick H. (1908), School of Mech. Engrg., Univ. of Ala., University, Ala.

SMITH, Mark Elmer (Junior, 1908), Struthers-Wells Co., Warren, and *for mail,* 246 W. 21st St., Erie, Pa.

SPIRO, Charles (1908), Genl. Mgr., Columbia Typewriter Mfg. Co., and *for mail,* 58 W. 97th St., New York, N. Y.

STEVENSON, J. Kennedy (Junior, 1908), Estimating Draftsman, Am. Loco., 50 Church St., and Princeton Club, Grammercy Park, New York, N. Y.

TAYLOR, Wyatt W. (Associate, 1908), Cons. Engr., 2 Rector St., New York, N. Y.

THRALL, Georg C. (1908), Genl. Mgr., Taylor Water Tube Boiler Co., Detroit, Mich.

WAERN, Adolph Wm. (1908), Bethlehem Steel Co., and *for mail,* 210 Broad St., Bethlehem, Pa.

WINTZER, Rudolph (1908), Power and Mining Mchy. Co., 115 Broadway, New York, N. Y.

WORTH, Charles C. (1908), Asst. Supt. Constr., N. Y. Edison Co., 55 Duane St., New York, N. Y.

WUERFEL, Geo. D. (1908), Member of Firm, Wuerfel & Miggett, Cons. and Mech. Engrs., 1125 Ohio Bldg., Toledo, O.

Gas Power Section

BROWN, Ernest C. (Affiliate, 1908), Pres., Rotary Meter Co., Editor, Progressive Age., 280 Broadway, New York, N. Y.

JONES, Hiram K. (Affiliate, 1908) Gas. Eng. Dept., People's Gas Light and Coke Co., 157 Michigan Ave., and 2521 Lowell Ave., Chicago, Ill.

PROMOTIONS

BOWEN, Harrison Seba (1895; 1908), Mech. Engr., R. W. Hunt & Co., 1121 Rookery Bldg., Chicago, and Wilmette, Ill.

EARLE, Samuel Broadus (1905; Associate, 1908), Assoc. Prof. of Mech. Engrg., Clemson College, Clemson College, S. C.

GORDON, Rea, M. (1902; Associate, 1908), Asst. Engr. of Tests, Solvay Process Co., and *for mail,* 533 S. Salina St., Syracuse, N. Y.

HALL, Rodney D. (1902; 1908), Asst. to Ch. Engr., The Snow Steam Pump Co., and *for mail,* 61 Anderson Pl., Buffalo, N. Y.

PERRY, Frank B. (1902; 1908), Mill Power Dept., Genl. Elec. Co., 84 State St., Boston, and *for mail,* 71 Athol St., Allston, Mass.

RICHMOND, Knight C. (1891; 1908), Cons. Engr., 526 Banigan Bldg., and 204 Angell St., Providence, R. I.

VAN WINKLE, Edward (1904; 1908), Cons. Patent Engr., Flat Iron Bldg., Madison Square, New York, and The Stuyvesant, 483 Park Pl., Brooklyn, N. Y.

WILKINS, I. Chester G. (1899; 1908), Mech. Engr., Thompson-Starrett Co., 51 Wall St., New York, N. Y.

RESIGNATIONS

SCHAEFFER, Louis C.

DEATHS

JONES, Edwin H.

COMING MEETINGS

AERONAUTIC SOCIETY
January 13, 20, 27, February 3, evenings, office Dr. Greene, 39th St. and Fifth Ave., New York. Secy., Wilbur R. Kimball.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 28, 1908–January 2, 1909, annual meeting, Baltimore, Md. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN GAS POWER SOCIETY
January 26, quarterly meeting, Minneapolis, Minn. Secy., R. P. Gillette.

AMERICAN GEOGRAPHICAL SOCIETY
January 26, 29 W. 39th St., New York, 8 p.m. Acting Secy., Geo. C. Hurlbut, 15 W. 81st St.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
January 15, monthly meeting, Toronto Section. Secy. *pro tem.*, W. H. Eisenheis, 1207 Traders' Bank Bldg.

AMERICAN INSTITUTE OF MINING ENGINEERS
February, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY
January 1, 2, Chicago Section, University of Chicago, Chicago, Ill. General Secy., F. N. Cole.

AMERICAN SOCIETY OF CIVIL ENGINEERS
January 20, February 3, 220 W. 57th St. Secy., C. W. Hunt.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
January 19–21, annual meeting, 29 W. 39th St., New York. Secy., W. M. Mackay.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
January 12, February 9, monthly meetings, 29 W. 39th St., New York, 8 p.m. Secy., Calvin W. Rice.

ASSOCIATION OF AMERICAN GEOGRAPHERS
January 1–2, annual meeting, Baltimore. Secy., Albert Perry, Brigham Hamilton, N. Y.

BOSTON SOCIETY OF CIVIL ENGINEERS
January 27, monthly meeting, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

CANADIAN RAILWAY CLUB
February 2, Montreal, Que. Secy., Jas. Powell, Care Grand Trunk Ry.

CANADIAN SOCIETY OF CIVIL ENGINEERS
January 14, General Section Meeting, 413 Dorchester St. W., Montreal, Que. Secy., Prof. C. H. McLeod.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Manitoba Branch
January 15, February 5, semi-monthly meetings, University of Manitoba. Secy., E. Brydone Jack.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Quebec Branch
January 15, annual meeting. Secy., P. E. Parent, P. O. Box 135, Quebec.
CANADIAN SOCIETY OF CIVIL ENGINEERS, Toronto Branch
January 7, annual meeting, January 28, regular meeting, 96 King St. W. Secy., T. C. Irving, Jr.
CAR FOREMEN'S ASSOCIATION OF CHICAGO
January 11, February 8. Secy., Aaron Kline, 326 N. 50th St.
CENTRAL ASSOCIATION OF RAILROAD OFFICERS
February 1, Indianapolis, Ind. Secy., G. B. Staats, Care Penna. Lines.
CENTRAL ASSOCIATION OF RAILROAD OFFICERS
January 11, February 8, Kansas City, Mo. Secy., F. H. Ashley, Gumbel Bldg.
CENTRAL ASSOCIATION OF RAILROAD OFFICERS
January 14, Toledo, O. Secy., H. M. Ellert.
CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
January 19, Rossin House, Toronto, Ont. Secy., C. L. Worth, Room 409, Union Sta.
CLEVELAND ENGINEERING SOCIETY
January 12, February 9, monthly meetings, Caxton Building. Secy., Joe C. Beardsley.
COLORADO SCIENTIFIC SOCIETY
February 6, monthly meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.
ENGINEERING ASSOCIATION OF THE SOUTH
January 19, monthly meeting, Nashville Section, Carnegie Library Bldg. Section S cy., H. H. Trabue, Berry Blk., Nashville.
ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA
February 2, monthly meeting, Iowa City, Ia. Secy., Dean Wm. G. Raymond.
ENGINEERS' CLUB OF BALTIMORE
February 6, monthly meeting. Secy., R. K. Compton, City Hall.
ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA
February 2, monthly meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher.
ENGINEERS' CLUB OF CINCINNATI
January 21, 25 E. 8th St. Secy., E. A. Gast, P. O. Box, 333.
ENGINEERS' CLUB OF TORONTO
January 14, etc., weekly meetings, 96 King St. W., Toronto, Ont. Secy., R. B. Wolsey.
ENGINEERS' CLUB OF PHILADELPHIA
January 23, February 6, 1317 Spruce St. Secy., H. G. Perring.
ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA
January 19, annual meeting, 803 Fulton Bldg., Pittsburgh, Pa. Secy., E. K. Hiles.
ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS
January 27–29, annual meeting, Great Northern Hotel, Chicago. Secy., E. E. R. Tratman, 1636 Monadnock Blk.
ILLUMINATING ENGINEERING SOCIETY
January 14, monthly meeting, New York Section, 29 W. 39th St., 8 p.m. Secy., P. S. Millar.

INDIANA ENGINEERING SOCIETY
January 14–16, Commercial Club, Indianapolis. Secy., Chas. Brossmann, 43 Union Trust Bldg.

INTERNATIONAL WATER LINES PASSENGER ASSOCIATION
January, Niagara Falls, Ont. Secy., M. R. Nelson, 379 Broadway, New York.

INTERSTATE SHIPMASTERS' ASSOCIATION
January, Washington, D. C.

IOWA ENGINEERING SOCIETY
January 13–14, annual meeting, Waterloo. Secy., A. H. Ford, Iowa City.

LOUISIANA ENGINEERING SOCIETY
January 9, annual meeting, 323 Hibernia Bldg., New Orleans. Secy., L. C. Datz.

MASSACHUSETTS STREET RAILWAY ASSOCIATION
January 13, February 10, Boston. Secy., Charles S. Clark, 70 Kilby St.

MICHIGAN ENGINEERING SOCIETY
January 12-15, Ann Arbor, Mich. Secy., Alba L. Holmes, Grand Rapids, Mich.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK
January 27, 29 W. 39th St., 8:15 p.m. Review of the Work of the Various Departments of the City Government for 1908, Robt. Ridgway. Secy., C. D. Pollock.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS
January 20, New York. Secy., C. C. Hildebrand, 7 E. 42d St.

NATIONAL ASSOCIATION OF CEMENT USERS
January 11–16, annual convention, Cleveland, O. Secy., George C. Wright, Harrison Bldg., Philadelphia, Pa.

NEW ENGLAND RAILROAD CLUB
January 12 February 9, Boston, Mass. Secy., Geo. H. Frazier, 10 Oliver St. Paper: Single Phase Railway System, N. W. Storer.

NEW ENGLAND STATES GAS ENGINEERS' ASSOCIATION
February 17, Boston, Mass. Secy., M. Gifford, 26 Central Sq., E. Boston.

NEW ENGLAND STREET RAILWAY CLUB
January 28, monthly meeting, American House, Boston, Mass.; March 25, annual meeting. Secy., John J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION
January 13, February 10, regular meetings. Secy., Willard Kent, Tremont Temple, Boston, Mass.

NEW YORK RAILROAD CLUB.
January 8, 15, 29 W. 39th St. Paper: Education and Organization of Railway Engineering Labor. Secy., H. D. Vought, 95 Liberty St.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS
January 12, etc., weekly meetings, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NORTHERN RAILWAY CLUB
January 23, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWESTERN ELECTRICAL ASSOCIATION
January 15–16, Hotel Pfister, Milwaukee, Wis. Papers: Series Tungsten Lighting; Increase of Central Station Load by Sub-Station to Nearby Hamlets; Keeping Track of Supplies and Contracting; The Tungsten Lamp;

Commercial Development of Practical Knowledge for Practical Men; Storage Battery Auxiliaries for Small Central Stations. Secy. Roger Kimball.

NORTHWEST RAILWAY CLUB

January 10, St. Paul, February 9, Minneapolis, Minn. Secy., T. W. Flannagan, Care Soo Line, Minneapolis.

NOVA SCOTIA SOCIETY OF ENGINEERS

January 14, monthly meeting, Halifax. Secy., S. Fenn.

OHIO ENGINEERING SOCIETY

January 26–28, Board of Trade Bldg., Columbus. Secy., Paul Hansen, 912 Harrison Bldg.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

January 26, monthly meeting, 48 Snow St.; June 22, annual meeting. Secy., T. M. Phetteplace.

PURDUE MECHANICAL ENGINEERING SOCIETY

January 20, February 3, fortnightly meetings, Purdue University, Lafayette, Ind., 6:30 p.m. Secy., L. B. Miller.

RAILWAY CLUB OF PITTSBURGH

January 22, monthly meeting, Monongahela House, Pittsburgh, Pa., 8 p.m. Secy., J. D. Conway, Genl. Office, P. & L. E. R. R.

RENSSELAER SOCIETY OF ENGINEERS

January 15, 29, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

RICHMOND RAILROAD CLUB

January 11, February 8, Richmond, Va. Secy., F. O. Robinson, Care C. & O. Ry.

ST. LOUIS RAILWAY ASSOCIATION

January 8, Palace of Transportation. Paper: The Ethics of Railroading, E. F. Kearney. Secy., B W. Frauenthal.

SCRANTON ENGINEERS' CLUB

January 21, Board of Trade Bldg. Secy., A. B. Dunning.

SHORT LINE RAILROAD ASSOCIATION

February 1, New York. Secy., Cromwell G. Macy, Jr., Nantucket Central R. R. 257 Broadway.

SOCIETY OF AUTOMOBILE ENGINEERS

Week of January 14, annual meeting, New York. Secy., C. B. Hayward, 915 Flatiron Bldg.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB

January 21, Atlanta, Ga. Secy., A. J. Merrill, 218 Prudential Bldg.

TECHNICAL SOCIETY OF BROOKLYN

January 15, February 5, bi-monthly meetings, Arion Hall, Arion Pl., Brooklyn, N. Y., 8:30 p.m. Paper: Electrical Power Transmission, Henry Pikler. Pres., M. C. Budell

TECHNICAL SOCIETY OF THE PACIFIC COAST

February 5, semi-monthly meeting, San Francisco, Cal. Secy., Otto von Geldern, 1978 Broadway.

TECHNOLOGY CLUB OF SYRACUSE

January 12, February 9, monthly meeting, 502 Bastable Blk., 8 p.m. Secy., Robert L. Allen.

WESTERN RAILROAD ASSOCIATION

January, annual meeting. Secy., Edw. P. Amory, 1330 Marquette Bldg., Chicago, Ill.

WESTERN RAILWAY CLUB

January 19, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Jos. W. Taylor, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS

January 13, etc., bi-weekly meetings, 1737 Monadnock Blk., Chicago. Secy., J. H. Warder.

Advertising Supplement to the Journal of
The American Society of Mechanical Engineers

Machine Shop Equipment

EXTRACTS FROM THE BOOK OF THE

COPIES OF THE BOOK

Multi-stop and Double Turners

FIG. 1 illustrates the advantage of the *double stop* for each position of the turret, and the *double* adjustment of each turner. This piece has six finished diameters and six shoulders, and is turned by only three turners, which occupy only three positions on the turret. This not only leaves the remaining positions free for other tools, but it saves the operator the time and energy required to run the turret slide back each time.

All this is obtained without complication, and without introducing any features that are annoying when not in use.

In addition to the double stop for each of the six positions of the turret, we have an extra stop, consisting of a pin which may be dropped into any one of the six holes at the rear of the turret slide. This makes it possible to borrow five extra stops for any one of the tools, and gives to this tool seven length or shoulder stops, and leaves one stop for each of the remaining tools.

FIG. 1

The illustrations, Figs. 2 and 3, give examples of what one tool can do in this machine on chuck work, when we take advantage of the seven length stops and the seven shoulder stops of the cross-feed head.

Of course, in general practice three or four stops for one tool are all that will be needed, but since the modern cutting steels have greater durability, there is nothing lost by giving each tool all the work it can do.

Outer face and all shoulders and diameters accurately finished to independent stops by one tool. When roughing and finishing cuts are required, the roughing tool can be set near enough to use the same stops that are accurately set for the finishing tool. When an extra tool is used to give a roughing cut it is set as indicated by dotted lines in Figs. 2 and 3.

We find it difficult to illustrate all of the classes of work that can be turned out by this machine, but a little thought will suggest

Springfield, Vt.
U. S. A.

Jones & Lamson

Germany, Holland, Belgium, Switzerland, Austria-Hungary, M. Koyemann, Charlottenstrasse 112 Dusseldorf, Germany.

HARTNESS FLAT TURRET LATHE

MAILED ON REQUEST

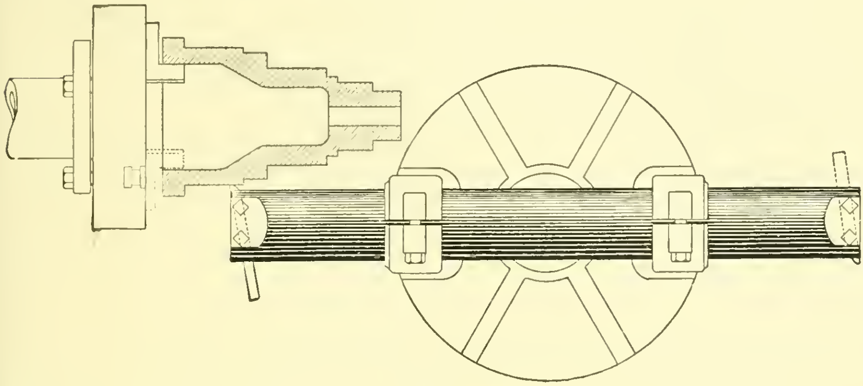


FIG. 2

many forms that may be readily handled in bar and chucking work, both steel and iron, on account of the many provisions for bringing both turret and cross slide up to fixed stops; either by power feed or by hand.

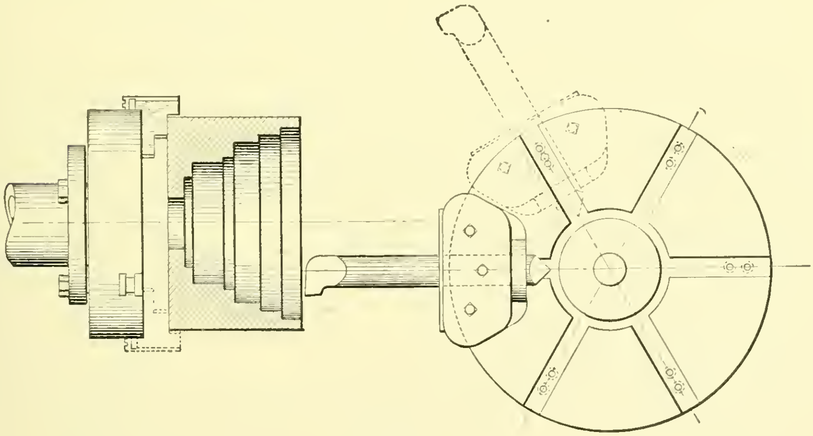


FIG. 3

Machine Company

Queen Victoria St.
London, England

France and Spain, Ph. Bonvillain and E. Ronceray, 9 and 11 Rue des Envierges, Paris. Italy, Adler & Eisenschitz, Milan.

NEWARK

GEAR CUTTING MACHINE CO.

66 UNION ST., NEWARK, N. J., U. S. A.

AUTOMATIC GEAR CUTTING MACHINES

GEARS AND GEAR CUTTING

HENRY E. EBERHARDT,
PRESIDENT

HENRY J. EBERHARDT,
SECRETARY

FRANK E. EBERHARDT
TREASURER

MANNING, MAXWELL & MOORE

INCORPORATED

Machine Tools, Electric Cranes
and Engineering Specialties

85-87-89 LIBERTY STREET, NEW YORK

Morse Twist Drill & Machine Co.

NEW BEDFORD, MASS., U. S. A.

Makers of Drills, Reamers, Cutters, Chucks, Taps, Dies, Arbors, Counterbores, Countersinks, Gauges, Machines, Mandrels, Mills, Screw Plates, Sleeves, Sockets, Taper Pins and Wrenches.

"American Swiss"

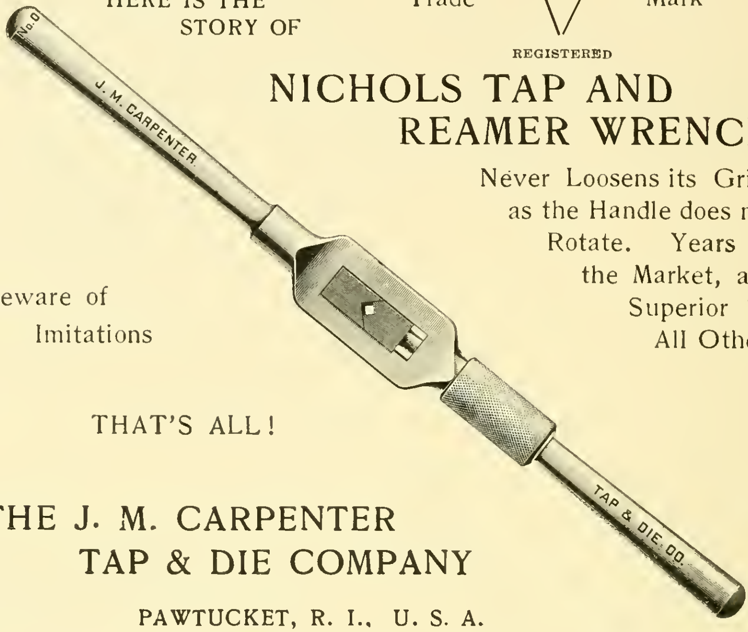
Files

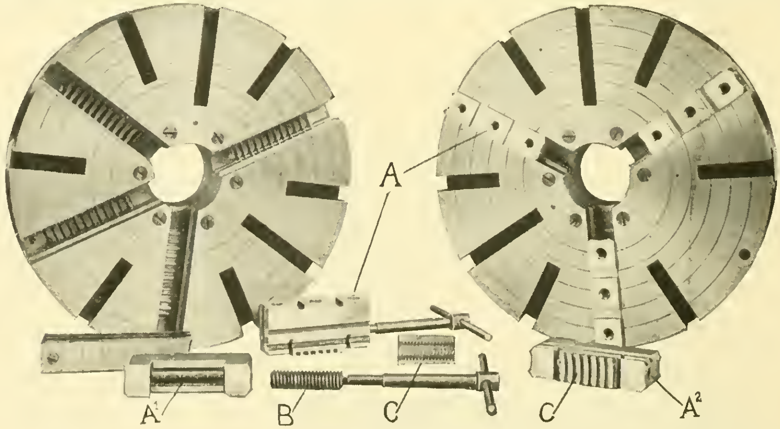
Warranted at least equal to the best Swiss Files

Samples on application to

E. P. REICHHELM & CO., 24 John St., New York

Principal Owners and Selling Agents of the American Swiss File and Tool Co.

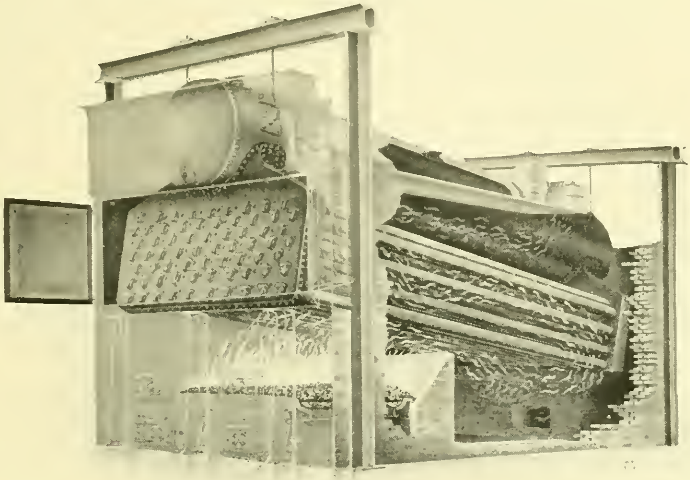

No. 0
J. M. CARPENTER
TAP & DIE. CO.

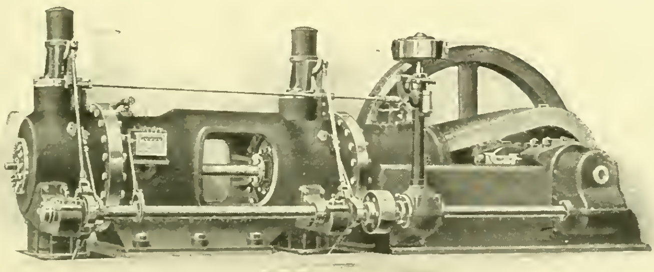

A
A[1]
B
C
C
A[2]

Advertising Supplement to the Journal of
The American Society of Mechanical Engineers

Power Plant Equipment


BALDT





THE DODGE

"EUREKA" AUTOMATIC WATER SOFTENER AND PURIFIER

destroys all scale forming matter in the feed water BEFORE it enters the heater, piping or boilers, thus making incrustation impossible.

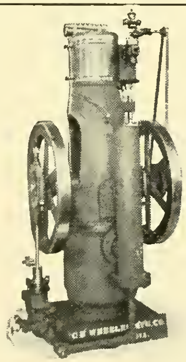
Soft water treated in the same way is also ideal for high class manufacturing work such as in the textile industry.

Full particulars will be supplied by addressing

DEPARTMENT J

DODGE MANUFACTURING CO.

MISHAWAKA, INDIANA



HIGH VACUUM APPARATUS

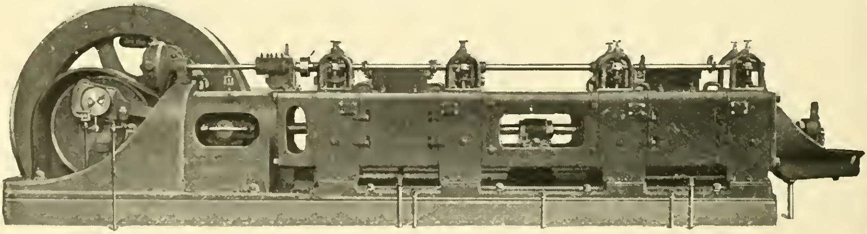
CONDENSERS
HEATERS
PUMPS

C. H. WHEELER MFG. CO.

PHILADELPHIA

New York, Chicago, Pittsburg, St. Paul, Charlotte, San Francisco

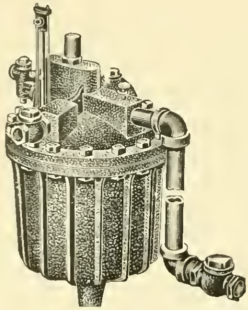
---



RIVERSIDE HEAVY DUTY DOUBLE-ACTING TANDEM GAS ENGINE (CLASS F)

Riverside Heavy Duty Gas Engines give steam engine service. Built in twelve types, seventy-two different sizes from 10 to 2500 H. P.

RIVERSIDE ENGINE COMPANY Oil City, Pennsylvania



Albany Steam Traps

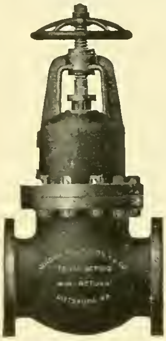
are the result of thirty-five years specializing in the production of Steam Traps

Owners and Engineers of Steam Plants are requested to write us for data concerning the

SPECIAL BUCKET RETURN TRAP

ALBANY STEAM TRAP CO., Albany, N. Y.

Established 1870. JAMES H. BLESSING, Pres. THOS. F. RYAN, Sec. and Treas.



The Anderson

TRIPLE ACTING

Non-Return VALVES

"Work Both Ways"

Protect Your Power Station with the Valves that are Absolutely Guaranteed

Armour & Co. Chicago, ordered 32 10″ Triple Valves

GOLDEN-ANDERSON Valve Specialty Co.

1032 Fulton Building Pittsburg, Pa.

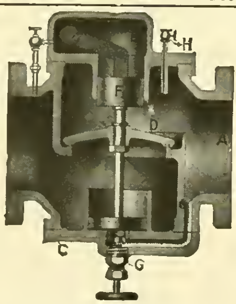
The Controlling Altitude Valve

maintains a uniform stage of water in standpipes, reservoirs or tanks.

NO FLOAT FIXTURES

No overflow in case of fire. Pressure. Valves closed by water and electricity

Valves and Traps
For Steam and Water Service



HOCHFELDT
Back Pressure and Relief Valve

You have been looking for this

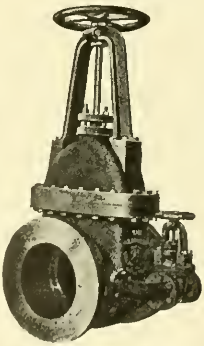
BACK PRESSURE VALVE

A Valve which can be used on either condensing or non-condensing systems. Instantly changed from one to the other. Send for catalogue of our Steam Specialties

Reducing Valves, Pump Regulators, Stop and Check Valves, Blow-off Valves, Etc.

THE JOHN DAVIS CO. Chicago, Ill.

New England Representative, W. G. Ruggles, 54 High St., Boston
New York Representative, J. H. Pearson, 122 Centre Street



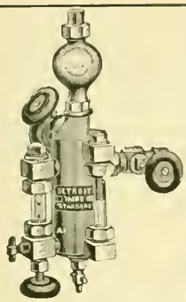
GATE VALVES

for 250 pounds working steam pressure on the *"Lenticular"* principle are the best for the purpose

Catalogue explains merits of Construction and Operation

The KENNEDY VALVE MANUFACTURING CO.

Elmira, N. Y. and 57 Beekman St. New York City



SOME ONE

of the 337 styles and sizes of the Detroit Sight Feed Lubricators will fill any requirement you may have, and fill it well

Over One Million in Service on the World's Engines

The genuine is sold low enough. Do not accept substitutes on your specifications for contractors and dealers' profit

CATALOGUE ?

DETROIT LUBRICATOR COMPANY DETROIT, U. S. A.

The reciprocating feed

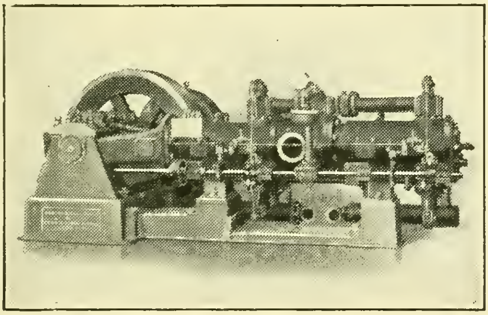
DETROIT STOKER

is recommended for large installations when coal is to be handled by machinery

IT BURNS ALL KINDS OF FUEL ECONOMICALLY

Send for our New Catalogue

Detroit Stoker and Foundry Co., Detroit, Mich.



DU BOIS GAS ENGINES

The most improved design, developed under expert experience and a guaranteed commercial success.

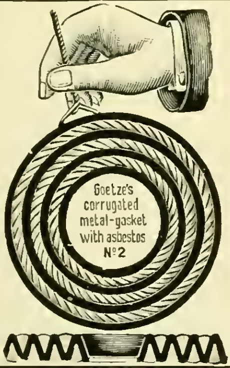
We build engines in sizes 5 to 375 horsepower—one, two and four cylinders, single acting, four cycle, horizontal types.

Electrical Service Engines, belted direct connected to generator. General Service Engines.

Write for our Catalog "M"

Du Bois Iron Works

Established 1877 DuBois, Pa.



LIGHTEN THE BURDENS OF THE ENGINEERS

and increase the earning capacity of the power plant by adopting the Goetze's Copper Gaskets. Nothing impairs their reliability and durability. Put them to the test on some of your most difficult propositions. The test tells. Write

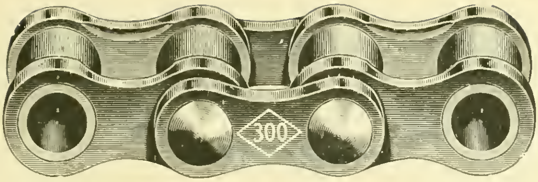
American Goetze-Gasket & Packing Company

530 E. 149th St., New York City

Advertising Supplement to the Journal of
The American Society of Mechanical Engineers

Hoisting and Conveying Machinery
Pumping Machinery and
Engineering Miscellany

Alphabetical Index to Advertisers Page 28
Classified List of Advertisers Pages 24 to 27



You Can Depend Upon A Diamond Chain Drive

Diamond Chains drove the Locomobile to victory in the Vanderbilt Cup Race; they helped Wright Bros. to break one world record after another, and today they are driving all kinds of machines where the utmost reliability is essential. If you have machinery with short, medium speed drives, don't be bothered with belt slip, wasted power and repair troubles; Diamond Chain Drives require practically no attention, won't let the speed ratio vary, will outlast other kinds of driving mechanism, will go into smaller space, and don't cost much either. There are no repair or up-keep expenses. Ask for booklet. *We make special chains to order.*

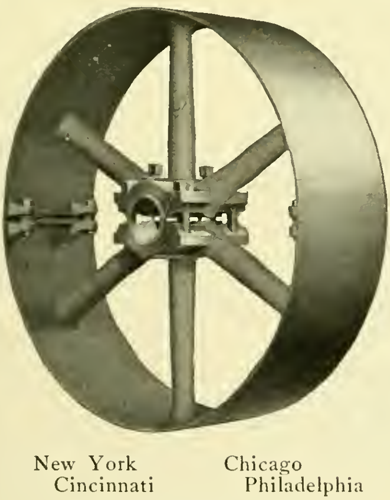
DIAMOND CHAIN & MFG. CO.

259 West Georgia St., Indianapolis, Ind.

No. 37

THE ONE WITHOUT THE WABBLE

THE DODGE "STANDARD" IRON SPLIT PULLEY



Is cast whole and the rim split by fracture at the parting lines, then bored, turned, ground and balanced.

Mounted on the shaft by bolting the rims together at their fractured parting lines, it is round and true.

Made of non-flexible metal it stays round.

Being balanced it runs true.

It looks right, acts right, is right. Use it and experience the acme of pulley satisfaction.

Dodge Manufacturing Co.

MISHAWAKA - INDIANA

New York Cincinnati Chicago Philadelphia St. Louis Boston Pittsburg Brooklyn

ENGINEERING SCHOOLS AND COLLEGES

CLARKSON SCHOOL OF TECHNOLOGY

Thomas S. Clarkson Memorial

ORGANIZED UNDER CHARTER OF THE UNIVERSITY OF THE STATE OF NEW YORK. Courses leading to degrees of Bachelor of Science in Chemical, Civil, Electrical and Mechanical Engineering, comprising four years of thorough training and resident college work in theory and practice of engineering. Copies of Clarkson Bulletin, published quarterly, mailed on application. WM. S. ALDRICH, *Director*.

POTSDAM, N. Y.

POLYTECHNIC INSTITUTE OF BROOKLYN

COURSE IN MECHANICAL ENGINEERING. Evening Post-Graduate Courses. Fred. W, Atkinson, Ph.D., President; W. D. Ennis, Member A. S. M. E., Professor Mechanical Engineering.

TUFTS COLLEGE

DEPARTMENT OF ENGINEERING. Civil, Mechanical, Electrical and Chemical Engineering. New laboratories and excellent equipment. Beautiful site within four miles of Boston. Preparatory department for students who have had engineering practice, but insufficient preparation for college work. For information concerning courses and positions of graduates, address,

PROF. G. C. ANTHONY, *Dean*.

TUFTS COLLEGE P. O., MASS.

THE RENSSELAER POLYTECHNIC INSTITUTE

Courses in Civil, Mechanical and Electrical Engineering and General Science leading to the degrees, C.E., M.E., E.E. and B.S.

Unsurpassed laboratories for Mechanical and Electrical Engineering.

Calalogue sent upon application, Troy, N. Y.

THE UNIVERSITY OF MICHIGAN

Ann Arbor, Mich.

DEPARTMENT OF ENGINEERING. Courses offered in Civil, Mechanical, Electrical, Chemical, Marine Engineering and Naval Architecture, Architecture and Architectural Engineering, and Geological Engineering. Four, five and six year courses. University attendance 5000; Engineering attendance 1350.

For special Bulletins address,

JAMES P. BIRD, *Secretary*.

NEW YORK UNIVERSITY SCHOOL OF APPLIED SCIENCE

DEPARTMENTS OF Civil, Mechanical and Chemical Engineering.

For announcements or information, address,

CHARLES HENRY SNOW, *Dean*

UNIVERSITY HEIGHTS, N. Y. CITY.

PROFESSIONAL CARDS

EARLE C. BACON

Member A. S. M. E.

Hoisting, Crushing and Mining Machinery

Havemeyer Building, NEW YORK

BERT. L. BALDWIN

Member A. S. M. E. and A. I. E. E.

Plans, Specifications and Superintendence of Manufacturing Buildings, Plants and Equipments of same.

Perin Building, CINCINNATI, OHIO.

D. HURLEY & COMPANY

Factory and Mill Engineering.

17 Custom House Street, PROVIDENCE, R. I.

J. G. O'NEIL

Member A. S. M. E.

Contracting Engineer; Boilers, Engines, Pumps and Steam Specialties.

304 The Rookery, CHICAGO, ILL.

CHAS. T. MAIN

Member A. S. M. E.

Mill Engineer and Architect.

Room 911, 45 Milk Street, BOSTON, MASS

SPECIAL RATES

Will be quoted on request for Professional Cards.

CLASSIFIED LIST OF ADVERTISERS

AIR CONDITIONING.

Carrier Air Conditioning Co., New York.

AIR WASHING.

Carrier Air Conditioning Co., New York.

ARBORS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

AUTOMATIC STOKERS.

Detroit Stoker & Foundry Co., Detroit, Mich.

BARRELS, TUMBLING.

Whiting Foundry Equipment Co., Harvey, Ill.

BELTING, LEATHER.

Schieren Co., Chas. A., New York.

BLOWERS, POSITIVE PRESSURE.

American Gas Furnace Co., New York.

BLOW PIPES AND BLOWERS.

American Gas Furnace Co., New York.

BLUE PRINTING MACHINES.

Buckeye Engine Co., Salem, O.

BOILERS.

Murray Iron Works Co., Burlington, Iowa.
Robb-Mumford Boiler Co., S. Framingham, Mass.

BORING MILLS.

Manning, Maxwell & Moore, New York.

BOLTS AND NUTS.

Russell, Burdsall and Ward Bolt and Nut Co., Port Chester, N. Y.

BOLT AND NUT MACHINERY.

Manning, Maxwell & Moore, New York.
National Machinery Co., Tiffin, O.

CAR HAULS, WIRE CABLE.

Jeffrey Mfg. Co., Columbus, O.

CARS, SCALE.

Alliance Machine Co., Alliance, O.

CASE HARDENING MACHINES.

American Gas Furnace Co., New York.

CASTINGS, SPECIAL HEAVY.

Hooven, Owens & Rentschler Co., Hamilton, O.

CENTERING MACHINES.

Whiton Machine Co., D. E., New London, Conn.

CHAINS, SPROCKET.

Diamond Chain & Mfg. Co., Indianapolis, Ind.

CHUCKS, DRILL.

Morse Twist Drill & Machine Co., New Bedford, Mass.
Whiton Machine Co., D. E., New London, Conn.

CHUCKS, LATHE.

Whiton Machine Co., D. E., New London, Conn.

CLUTCHES, FRICTION.

Dodge Mfg. Co., Mishawaka, Ind.

COAL CUTTERS.

Jeffrey Mfg. Co., Columbus, O.

COMPRESSORS, AIR.

Riverside Engine Co., Oil City, Pa.

COMPRESSORS, GAS.

Riverside Engine Co., Oil City, Pa.

CONDENSERS, SURFACE, JET AND BAROMETRIC.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

CONVEYORS, AUTOMATIC.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

COOLING.

Carrier Air Conditioning Co., New York.

COPPER CONVERTING MACHINERY.

Alliance Machine Co., Alliance, O.

COUNTERBORES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

COUNTERSHAFTS.

Builders Iron Foundry, Providence, R. I.
Dodge Mfg. Co., Mishawaka, Ind.

COUPLING, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

CRANES.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Manning, Maxwell & Moore, New York.
Whiting Foundry Equipment Co., Harvey, Ill.

CUPOLAS, FOUNDRY.

Whiting Foundry Equipment Co., Harvey, Ill.

CUTTERS, MILLING.

Morse Twist Drill & Machine Co., New Bedford, Mass.

DEHUMIDIFYING.

Carrier Air Conditioning Co., New York.

DRILLS.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.

DRILLS, PORTABLE.

General Electric Co., Schenectady, N. Y.

DRAFTSMAN'S SQUARE.

Kelsey, D. J., New Haven, Conn.

DYNAMOS.

General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELECTRICAL MACHINERY.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELEVATORS.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

ELEVATING AND CONVEYING MACHINERY.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

ENGINES, GAS.

Buckeye Engine Co., Salem, O.
National Meter Co., New York.
Riverside Engine Co., Oil City, Pa.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

ENGINES, STEAM.

American Engine Co., Bound Brook, N. J.
Buckeye Engine Co., Salem, O.
Hooven, Owens & Rentschler Co., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Ridgway Dynamo & Engine Co., Ridgway, Pa.
St. Louis Iron & Machine Works, St. Louis, Mo.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

FILES.

American Swiss File and Tool Co., New York.
Reichhelm & Co., E. P., New York.

FORGES, GAS.

American Gas Furnace Co., New York.

FOUNDRY EQUIPMENT.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, ANNEALING AND TEMPERING.

American Gas Furnace Co., New York.

FURNACES.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, GAS.

American Gas Furnace Co., New York.

GAS GENERATORS.

American Gas Furnace Co., New York.

GASKETS.

American Goetze-Gasket & Packing Co., New York.

GASKETS, COPPER.

American Goetze-Gasket & Packing Co., New York.

GAS PRODUCERS.

Struthers-Wells Co., Warren, Pa.

GAGES, WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Manning, Maxwell & Moore, New York.

GEAR CUTTING MACHINES.

Manning, Maxwell & Moore, New York.
Newark Gear Cutting Machine Co., Newark, N. J.
Whiton Machine Co., D. E., New London, Conn.

GEARS.

Dodge Mfg. Co., Mishawaka, Ind.

GENERATING SETS.

American Engine Co., Bound Brook, N. J.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

GOVERNORS, PUMP.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.

GRAPHITE.

Dixon Crucible Co., Jos., Jersey City, N. J.

GRINDERS, TOOL.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Pratt and Whitney Co., Hartford, Conn.

GRINDING AND POLISHING MACHINERY.

Builders Iron Foundry, Providence, R. I.

HAMMERS, STEAM.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

HANGERS, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

HEATERS, FEEDWATER.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

HEATING MACHINES.

American Gas Furnace Co., New York.

HOISTS.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTING AND CONVEYING MACHINERY.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

HUMIDIFYING.

Carrier Air Conditioning Co., New York.

HUMIDITY CONTROL, AUTOMATIC

Carrier Air Conditioning Co., New York.

HYDRAULIC MACHINERY.

Alliance Machine Co., Alliance, O.

INJECTORS.

Detroit Lubricator Co., Detroit, Mich.
Manning, Maxwell & Moore, New York.
Ohio Injector Co., Wadsworth, O.

LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.
Warner & Swasey Co., Cleveland, O.

LATHES, BENCH.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, CHUCKING.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, TURRET.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, FOOT POWER.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, ENGINE.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, WOOD.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LOCOMOTIVES. ELECTRIC.

Jeffrey Mfg. Co., Columbus, O.

LUBRICANTS.

Dixon Crucible Co., Jos., Jersey City, N. J.

LUBRICATORS.

Detroit Lubricator Co., Detroit, Mich.
Ohio Injector Co., Wadsworth, O.

MACHINERY DEALERS.

Manning, Maxwell & Moore, New York.

MANDRELS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

METAL, ANTI-FRICTION.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METALS, BEARING.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METERS, VENTURI.

Builders Iron Foundry, Providence, R. I.

METERS, WATER.

National Meter Co., New York.

MILLING MACHINES.

Manning, Maxwell & Moore, New York.

MOTORS, ELECTRIC.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

OILING DEVICES.

Detroit Lubricator Co., Detroit, Mich.

PIPE CUTTING AND THREADING MACHINES.

Manning, Maxwell & Moore, New York.

PRESSES, HYDRAULIC.

Alliance Machine Co., Alliance, O.

PISTONS, METAL FOR FACING.

Allan & Son, A., New York.

PAPER MILL MACHINERY.

Sandusky Foundry & Machine Co., Sandusky, O.

PLANERS, METAL.

Manning, Maxwell & Moore, New York.

PULLEYS.

Dodge Mfg. Co., Mishawaka, Ind.

PUMPS, CENTRIFUGAL.

Jeanesville Iron Works Co., Hazleton, Pa.
Morris Machine Works, Baldwinsville, N .Y.
Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, GAS DRIVEN.

Riverside Engine Co., Oil City, Pa.

PUMPS, VACUUM.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, PRESSURE.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUNCHES AND SHEARS.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

REAMERS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

REGULATORS, PUMP.

Davis Co., John, Chicago, Ill.

REGULATORS, FEED WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

RIVET HEADERS.

National Machinery Co., Tiffin, O.

RIVETERS, HYDRAULIC.

Alliance Machine Co., Alliance, O.

ROLLING MILL MACHINERY.

Alliance Machine Co., Alliance, O.

SCREW PLATES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

SEPARATORS, STEAM AND OIL.

Albany Steam Trap Co., Albany, N. Y.

SHAPERS.

Manning, Maxwell & Moore, New York.

SMOKELESS FURNACE.

Detroit Stoker & Foundry Co., Detroit, Mich.

SOCKETS AND SLEEVES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

SPROCKETS.

Diamond Chain & Mfg. Co., Indianapolis, Ind.

STEEL PLATE CONSTRUCTION.

Robb-Mumford Boiler Co., South Framingham, Mass.
Struthers-Wells Co., Warren, Pa.

STOKERS, MECHANICAL.

Detroit Stoker & Foundry Co., Detroit, Mich.

TAPPING MACHINES AND ATTACHMENTS.

F. A. Errington, New York.

TAPS AND DIES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

TRACK, INDUSTRIAL.

Whiting Foundry Equipment Co., Harvey, Ill.

TRAPS, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

TRANSMISSION MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Link Belt Co., Philadelphia, Pa.

TURBINES, STEAM.

General Electric Co., Schenectady, N. Y.
Hoover, Owens & Rentschler Co., Hamilton, O.

TURRET LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Warner & Swasey Co., Cleveland, O.

UPSETTING AND FORGING MACHINES.

National Machinery Co., Tiffin, O.

VALVE DISCS, METALLIC.

Allan & Son, A., New York.

VALVES, AUTOMATIC.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BACK PRESSURE.

Davis Co., John, Chicago, Ill.
Kennedy Valve Co., Elmira, N. Y.
Walch & Wyeth, Chicago, Ill.

VALVES, BOILER STOP.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BLOW-OFF.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.

VALVES, CHECK.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, FLOAT.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, GATE.

Albany Steam Trap Co., Albany, N. Y.
Kennedy Valve Co., Elmira, N. Y.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, GLOBE.

Albany Steam Trap Co., Albany, N. Y.
Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, HYDRAULIC.

Nelson Valve Co., Philadelphia, Pa.

VALVES, NON-RETURN.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, RADIATOR.

Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.

VALVES, REDUCING.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, REGULATING.

Davis Co., John, Chicago, Ill.

VALVES, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, SWING GATE.

Walch & Wyeth, Chicago, Ill.

WATER COOLING TOWERS.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

WATER TOWERS.

Struthers-Wells Co., Warren, Pa.

WATER COLUMNS.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.

WATER SOFTENERS AND PURIFIERS.

Dodge Mfg. Co., Mishawaka, Ind.

WIRE NAIL MACHINES.

National Machinery Co., Tiffin, O.

WIRE ROPE.

Roebling's Sons Co., John A.

WOOD POLISHING WHEELS.

Builders Iron Foundry, Providence, R. I.

WOODWORKING MACHINERY.

Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.

WRENCHES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

ALPHABETICAL LIST OF ADVERTISERS

THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

FEBRUARY 1909

NEXT MONTHLY MEETING FEBRUARY 23
NOTE CHANGE OF DATE

FEBRUARY 1909 VOL. 31 No. 2

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED AT 2427 YORK ROAD - - - - BALTIMORE, MD.
EDITORIAL ROOMS, 29 W. 39TH STREET - - - - NEW YORK

CONTENT

Contents continued on next page

THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.

Price, one dollar per copy—fifty cents per copy to members. Yearly subscription, $7.50; to members, $5.

Application filed for entry at the Postoffice, Baltimore, Md., as second-class mail matter under the act of March 3, 1879

CONTENTS—Continued

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 FEBRUARY 1909 NUMBER 2

POSTPONEMENT OF THE FEBRUARY MEETING

THE February meeting will be held on Tuesday, February 23. The subject of Safety Valves will be opened up by Mr. F. M. Whyte, member of the Council. Important contributions to this subject will be made by prominent manufacturers.

THE SPRING MEETING

The spring meeting will be held in Washington, D. C., early in May. At the time of the meeting held there ten years ago, it was urged that it would be desirable to hold conventions of the Society in Washington at stated intervals. This suggestion met with general approval, as being an advantage to the profession as well as emphasizing the national character of the organization.

The many places of interest in Washington will be an added incentive to attendance, and those who were at the previous convention will recall the courtesy offered them in their visits to the White House, the Navy Yard, the Washington Monument, the Library of Congress, the Patent Office; and the trip to Mt. Vernon, where appropriate ceremonies were held at the tomb of Washington, and a tree planted in the name of the Society among the memorial trees along the driveway of the Mt. Vernon estate.

A convention held in Washington promises a great deal besides the interest of the professional sessions.

THE FORMATION OF SECTIONS

The formation of sections is becoming a very welcome activity of the Society, and is one of the steps toward expansion which the Council and membership are pleased to see.

The Gas Power Section, which was the first section formed, successfully met a need for organized coöperation to encourage the exchange of information and experience, so necessary in that particular industry. This branch of engineering was growing so rapidly, and so much needed to be said and written, that it was obvious that a section should be devoted to it. It could then hold meetings, and give as much time to discussion as seemed desirable. The benefit derived and the continued interest has been very great. The Society would be pleased to see further steps along the same lines.

Another welcome movement is for student affiliate sections, which may be formed at schools of engineering. Stevens Institute of Technology leads with the first section. An account of their work will be found elsewhere in these columns. Cornell has been granted permission to form a section and two other universities have applied.

The student societies may have complete independence and self-control under their own by-laws, subject only to such limitations as may be set by the Council. They must have as Honorary President a member of this Society, and preferably the Professor of Mechanical Engineering in the institution in which the section exists. With such a guiding hand, the activities of the affiliates may be developed in harmony with the policy and traditions of the Society.

Upon payment of $2 per year, students may become affiliates, receive "The Journal," and attend all meetings.

STEVENS INSTITUTE ENGINEERING SOCIETY, AFFILIATED WITH THE A. S. M. E.

The Stevens Institute Engineering Society formed the first student branch affiliated with the Society under the rules for such sections recently enacted by the Council.

The Honorary President, who by requirement must be a member of the A. S. M. E., is Dr. Alex. C. Humphreys, President of Stevens Institute of Technology. The President of the Section is Mr. E. Nyland, of the senior class. A list of the 29 affiliates will be found under "Changes in Membership" in this issue.

A meeting of the Section has been held, which was addressed by Professor Ganz, head of the department of Electrical Engineering at

Stevens, on the subject of Electrolysis. The Branch has also made an inspection trip to the Western Electric Company's West Street works, New York.

The Stevens Society, believing that the interest of the members can be held only by thought and work on the part of the members, has opened a competition for the best write-up of an inspection trip, or of a general or special lecture. It is also the aim to encourage questions at the close of the lectures, to clear up points not entirely understood, and open avenues for discussion.

The policy of the Branch is to open their lectures to all students; but special lectures and inspection trips may be participated in only by members.

We feel that the Stevens Branch has taken an energetic step in the right direction in their inspection trips, the competition reports, and especially in their policy of holding the interest of the members by insisting upon work from them. The importance of discussion and coöperation should be learned early and emphasized. The value of conducting meetings; of coming together with a common interest for discussion; of having an organization which provides for visits and inspection trips, invites lectures and at the close of the college course places its members in direct line for membership in the national organization of their profession, ought to make an appeal to progressive, ambitious young engineering students.

JANUARY MEETING

The monthly meeting was held in the Engineering Society's Building on the evening of the twelfth, at which the paper on "The Transmission of Power by Leather Belting" was given by Carl G. Barth. The meeting was largely attended, and of unusual interest. The author used the lantern to assist him in his explanations of the diagrams in the published paper, and these views were supplemented by others showing the practical application of belting under different conditions.

Many engineers participated in the discussion, which was varied in character, and appreciative of the magnitude and usefulness of the work accomplished by the author in the development of his theory of belting, and which so effectually supplements the results of earlier investigators. The paper was discussed technically, and also by those familiar with the installations made by the author, where greatly improved performance of belting has been secured.

Following the discussion which pertained strictly to the subject matter of the paper, was a general discussion upon the transmission of power by electricity and by rope, and by the modern types of chains used for power transmission. Written discussions were submitted by A. F. Nagle, Prof. Wm. W. Bird, Prof. C. H. Benjamin, H. K. Hathaway, and Prof. L. P. Breckenridge. Oral discussions were given by Henry R. Towne, Wilfred Lewis, W. D. Hammerstadt, Fred W. Taylor, Charles Robbins, Geo. N. Van Derhoef, Walter L. Allen, Dwight V. Merrick, Fred A. Waldron, S. B. Flint, and A. A. Carey.

APPOINTMENT OF MR. FREEMAN

Mr. John R. Freeman, Past President of the Society, has been appointed by President Roosevelt a member of the Board of Engineers, to accompany President Taft on his visit to the Panama Canal.

THE NEW OFFICERS OF THE SOCIETY

Vice-Presidents

GEORGE M. BOND

Mr. George M. Bond graduated from Stevens Institute of Technology, in 1880, receiving the degree of Mechanical Engineer. Several months previous to his graduation he was associated with Prof. Wm. A. Rogers, professor of astronomy at Harvard College Observatory, Cambridge, in the work of establishing, on a scientific basis, standards for linear measurement. This work was carried out and practically applied through the liberal spirit of The Pratt and Whitney Co., of Hartford, Conn., the keen appreciation of the value of such an investigation being a distinctive characteristic of the late Francis A. Pratt, then president of the company, and a charter member of this Society. Mr. Bond was engaged in this work and its subsequent development with the above company from 1880 until 1902, as manager of the standards and gage department. Since then he has been engaged in special work in relation to standards and their practical application.

Mr. Bond is a member of the American Society of Civil Engineers, the Engineers' Club, and the Transportation Club, and is a Fellow of the American Association for the Advancement of Science. He was President of the Alumni Association, Stevens Institute of Technology, 1886–1887, and Alumni Trustee, 1895–1898.

Mr. Bond served as Manager of the Society from 1888–1891 and has presented the following papers: Standard Measurements, A Standard Gage System, Standard Pipe and Pipe Threads.

He has done important work on the Committee on Standards for Pipe Unions, Standard Gages for Thickness, and Standard Proportions for Machine Screws.

R. C. CARPENTER

Dr. Rolla Clinton Carpenter was born in Michigan, June 26, 1852. He received his early education in the schools and colleges of that state, and was graduated from the University of Michigan with the class of 1875, as a civil engineer. He spent one year in actual rail-

road construction, and afterward accepted a position as Professor of Mathematics and Engineering in the Michigan Agricultural College, in which position he remained until 1890, when he accepted the professorship in Experimental Engineering at Cornell. He received the degree of C.E. from his alma mater; M.S. from Michigan Agricultural College, and M.M.E. and LL.D. from Cornell.

While at Lansing, Doctor Carpenter was consulting engineer for the Lansing Engine and Iron Works, in which capacity he designed the governor for their automatic engine. At this time, he made a large number of tests to determine the friction of various engines under different conditions. He has been engineer for several important constructions and installations in the state of Michigan; engineer for electric railroad companies; has made plant and engine tests, and has designed heating and ventilating systems for public buildings. He is also the designer of a number of the smaller pieces of apparatus used in steam and experimental engineering; among these are a coal calorimeter, a steam calorimeter, and a steam separator.

Doctor Carpenter is the author of text books on Experimental Engineering, and on Heating and Ventilating. In connection with Prof. H. Diederichs he has published a book on Internal Combustion Engines. Besides these larger works, he has written many articles of scientific and engineering interest for this Society and for various engineering periodicals.

Doctor Carpenter was a judge at the World's Columbian Exposition in the Department of Machinery, acting in addition on a special committee from the Department of Transportation, to award diplomas to exhibitors of car heating devices. He was a judge of power and machinery exhibits at the Pan-American Exposition and at the Jamestown Exposition. He is a member of the American Institute of Mining Engineers, American Society of Refrigerating Engineers, Past President of Heating and Ventilating Engineers, and Automobile Engineers. He is a member of the college fraternity of Delta Tau Delta, of the honorary society of Sigma Psi and of several clubs among which may be mentioned the Town and Gown and Craftsman Club, Ithaca, N. Y., the Engineers' Club, New York.

F. M. WHYTE

Mr. F. M. Whyte graduated with the degree of Mechanical Engineer, Cornell University, 1889. Since that time he has been interested in the rolling-equipment branch of railroad work, being connected

at various times with the B. &. O., the Chicago & Northwestern and the elevated roads in Chicago. He is now General Mechanical Engineer of the New York Central Lines. Mr. Whyte has been Secretary of the Western Railway Club and also of the New York Railroad Club. He has written several papers for the technical press.

Managers

H. L. GANTT

Mr. H. L. Gantt was born in Maryland, May 20, 1861. He received his early training at the McDonogh School near Baltimore. In 1880 he received the degree of A.B. from Johns Hopkins University, and the degree of M.E. was conferred upon him by the Stevens Institute of Technology in 1884.

For two years he was in the employ of the Midvale Steel Company. He was with the American Steel Casting Co., one year, as superintendent of their Thurlow, and later their Norristown plant. For two years he was associated with the Simonds Rolling Machine Co., acting as superintendent most of the time. He accepted a position with the Bethlehem Steel Co., helping Mr. F. W. Taylor to install his system of management. He was with this company two and a half years, after which he acted as consulting engineer for the American Locomotive Co., and subsequently for a number of plants. He is a member of the Society of Naval Architects and Marine Engineers.

He has written the following papers for this Society: A Bonus System of Rewarding Labor; A Graphical Daily Balance in Manufacture; Training Workmen in Habits of Industry and Coöperation. He has written for the Engineering Magazine, The Coöperation of Labor, and presented Scientific Methods and the Labor Problem before the International Congress of Arts and Sciences, St. Louis, September 23, 1904.

I. E. MOULTROP

Mr. Irving E. Moultrop was born in Marlboro, Mass., July 1865, and received his education at the public schools in Framingham, Mass. After graduating from the high school at the age of eighteen he entered the employ of the Whittier Machine Co., Boston, Mass., as apprentice. During the three years of apprenticeship he prepared himself for a draftsman, by studying in evening schools and doing other work during his spare time.

On the expiration of his apprenticeship, he entered the drawing-room of the same company, and at the end of two years was advanced to the position of head-draftsman. He held this position until January 1892, when he accepted a position with the Edison Electric Illuminating Co., of Boston, in charge of their drawing-room. Mr. Moultrop is at present mechanical engineer for the company, having charge of all construction work except the transmission work and electrical work done outside of the stations. During a part of this time he was in charge of the company's repair shops. Three years ago, he was sent abroad by the company to investigate the steam turbine situation in England and on the continent.

Mr. Moultrop is a member of the Boston Society of Civil Engineers, the National Electric Light Association, and the New England Street Railway Club. He has served on the Steam Turbine and the Gas Engine Committees of the National Electric Light Association.

Mr. Moultrop is joint author, with Mr. R. E. Curtis, of Recent Construction at the Atlantic Avenue Station of the Edison Electric Illuminating Co., of Boston, which was presented at the Spring meeting of this Society, held in Boston, Mass., in 1902.

WILL J. SANDO

Will J. Sando was born April 9, 1864. His practical experience began with a five-years apprenticeship to the machinists' trade after which he spent two years as mechanical draftsman with the Dickson Mfg. Company, of Scranton, Pa., and was then engaged as draftsman and inspector of all kinds of machinery for the Calumet & Hecla Mining Company. Mr. Sando has also acted as draftsman-in-charge of the drawing office in connection with the U. S. Government engineers at the Wm. Cramp & Sons Shipyards, Philadelphia, Pa.; inspector of machinery, and later superintendent of pumping stations of the Metropolitan Water Board, Commonwealth of Massachusetts; chief engineer and manager of the pumping engine department of the International Steam Pump Company, New York; engineer of the pumping department of the Burr-Herring-Freeman Commission on additional water supply for the City of New York; and, since September 1, 1904, as manager of the pumping engine and hydraulic turbine department of the Allis-Chalmers Company, Milwaukeee, Wis.

Mr. Sando is a member of the Boston Society of Civil Engineers, New England Water Works Association, American Water Works

Association, American Society for the Advancement of Science, American Academy of Political and Social Science, Engineers' Club, New York, Machinery Club, New York, Country Club, Pittsburgh; Milwaukee Club and Country Club, Milwaukee.

MEETING OF THE COUNCIL

There were present at the January meeting of the Council, Tuesday, January 12, 1909, Messrs. Bond, Basford, Hutton, Gantt, Miller, Moultrop, Smith, Waitt, Whyte and the Secretary. Mr. Jesse M. Smith, President, occupied the chair.

The minutes of the previous meeting were read and approved.

The President reported the appointment of members to the vacancies on the Standing Committees, and a meeting of all the committees on Tuesday, January 5, when they organized.

Hudson-Fulton Commission. The President reported the receipt of an invitation from the Committee on Historical Exhibits of the Hudson-Fulton Commission, to meet with the Presidents of the other national engineering societies to consider the desirability of holding a loan exhibition showing our development in steam navigation.

It was voted that the President accept the invitation and that our participation in the matter be referred to the Executive Committee for consideration and report.

Deaths. The following deaths were reported: E. L. Jennings, W. E. Hill, E. H. Jones and A. R. Wolff, Charter Member.

Involute Gearing. It was voted that the President appoint a committee of five members to formulate standards for Involute Gears and present them to the Council.

It was voted that the Secretary make an effort to collect from members of the Society who are in arrears for purchases and dues; upon failure to collect to secure the return of the purchases; if that is not possible to institute replevin suits. Recommendation was made that such members be dropped from the rolls of the Society.

International Standard for Pipe Threads. It was voted that the final report of the Committee on International Standard for Pipe Threads be received and placed on file and a copy transmitted to the honorary Vice-President of the Society representing the Society at the Paris Congress and that the same be published in the Transactions.

OTHER SOCIETIES

MEETINGS A. I. M. E.

A meeting of the American Institute of Mining Engineers will be held at New Haven, Conn., on Tuesday, February 23. Sessions held in North Sheffield Hall of Yale University.

The following subjects will be discussed: The Conservation of Natural Resources; A Sea Level Canal in Panama; The Technical Education of Mining Engineers, etc.

About thirty papers, including the above and miscellaneous subjects, will be read. The Hammond Laboratory of the Yale University, the works of the National Pipe-Bending Company, the plant of the New Haven Gas Company, the Bigelow Boiler Works, the Farrel Foundry and Machine Works, the brass and copper rolling mills of the Coe Brass Company, the Locomobile works, the American Tube and Stamp Works and the works of the Crane Company, valve manufacturers, will be visited.

The governing board of the Sheffield Scientific School will give a reception to the members and guests at Byers Memorial Hall.

Dr. R. W. Raymond, Secretary of the Institute, will deliver a lecture on the Influence of Geology upon the History of Jamaica. Visits will also be made to the Cos-Cob Plant of the N. Y., N. H. & H. R. R. Co.

All members of this Society are cordially invited to attend the above sessions, and any intending to accept are invited to correspond with Dr. Raymond in order to secure the necessary hotel accommodations.

Election of Officers. The annual business meeting of the Institute will be held at No. 29 West 39th Street, New York, on February 16 at 11 o'clock. At this meeting three directors of the corporation, and officers and members of the council, will be elected.

MEETINGS A. I. E. E.

The American Institute of Electrical Engineers held a meeting on January 8, 1909. The Secretary announced that 114 Associates had been elected, and five Associates transferred to the grade of Member. Professor Elihu Thomson, electrician of the General Electric Com-

pany, read a paper entitled, Conditions Affecting Stability in Electric Lighting Circuits. The paper was discussed by Messrs. A. E. Kennelly, Alex Dow, E. W. Rice, Jr., Dugald C. Jackson, C. M. Green, John B. Taylor, C. P. Steinmetz, and Elihu Thomson.

The American Institute of Electrical Engineers will hold their February Meeting in the auditorium of the Engineering Societies Building, February 19, 1909, at 8 p.m. Dr. Charles P. Steinmetz, consulting engineer of the General Electric Company, Schenectady, N. Y., will present a paper entitled Prime Movers.

MEETINGS TO BE HELD IN THE ENGINEERING SOCIETIES BUILDING

The following meetings will be held in the Engineering Societies Building during February and March.

Date	Society	Secretary	Time
Feb. 2	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 4	Blue Room Engineering Society	W. D. Sprague	8:00
" 5	Explorers Club	H. C. Walsh	8:30
" 9	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 11	Illuminating Engineering Soc	P. S. Millar	8:00
" 12	American Inst. of Electrical Engrs	R. W. Pope	8:00
" 16	N. Y. Soc. of Accountents & Bkprs	T. L. Woolhouse	8:00
" 16	N. Y. Telephone Society	T. H. Laurence	8:00
" 17	N. Y. Electrical Society	G. H. Guy	8:00
" 19	N. Y. Railroad Club	H. D. Vought	8:15
" 23	American Geographical Society	A. A. Raven	8:00
" 23	N. Y. Society Accountants & Bkprs	T. L. Woolhouse	8:00
" 23	American Soc. of Mech. Engrs	Calvin W. Rice	8:15
" 24	Municipal Engrs. of N. Y	C. D. Pollock	8:15
Mar. 2	N. Y. Society Accountants & Bkprs	T. L. Woolhouse	8:00
" 4	Blue Room Engineering Society	W. D. Sprague	8:00
" 5	Explorers Club	H. C. Walsh	8:30
" 9	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 9	American Soc. of Mech. Engrs	Calvin W. Rice	8:15
" 11	Illuminating Engineering Society	P. S. Millar	8:00
" 12	American Inst. of Electrical Engrs	R. W. Pope	8:00
" 16	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 16	N. Y. Telephone Society	T. H. Laurence	8:00
" 19	N. Y. Railroad Club	H. D. Vought	8:15
" 23	American Geographical Society	A. A. Raven	8:00
" 23	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 24	Municipal Engineers of N. Y	C. D. Pollock	8:15

GENERAL NOTES

INTERNATIONAL CONSERVATION CONGRESS

The following in regard to the International Conservation Congress, which President Roosevelt has called to meet in Washington, February 18, is taken from the January 9 issue of the Outlook:

President Roosevelt requested Earl Grey, Governor-General of Canada, and President Diaz of Mexico to send representatives to attend a conference on conservation of our natural resources of North America to be held at Washington, February 18, 1909. The proposed conference grows out of the two conservation conferences already held at Washington. At the first of these, last May, governors of states and territories were the principal conferees with the President. At the second, a month ago, the conferences were increased by the national conservation commission members appointed last summer.

Even before the first conference was called many observers felt that the movement should be international in character. It was, however, deemed advisable not to enlarge its national character at that time. Last spring, Mr. Bryce, British Ambassador at Washington, remarked at the Canadian Club dinner in New York City that the utmost gratitude was due to President Roosevelt for calling attention to the magnitude and gravity of the problem of natural resource conservation, declaring that the question interested Canadians almost as much as it did our own people, and that in any event Canadians ought to be stirred up to preserve their own forests. Mr. Bryce was illustrating the way in which the example of each country might be helpful to the other, but he could have added that we of this side of the border might well imitate certain Canadian methods of forest preservation long in successful operation.

At the tariff hearings at Washington and the subsequent discussions, a great deal was said about Canadian lumber.

Some observed that Canadian forests are rich both in quantity and quality, others maintained the contrary. Some said that if we make lumber free, we may draw more fully upon Canadian forests and then spare our own. Others said that just the contrary would be the case, that the introduction of cheap Canadian lumber would cause an increased cutting of our hard woods.

To conserve resources in their entirety we must naturally know not only about our own but about those across the two borders.

The plans of the Reclamation Service have been increased to cover an acreage of about two million three hundred thousand acres, at an estimated cost of about ninety million dollars. All official communications or reports from and to executive officers of the territories and territorial possessions of the United States are

now transmitted through the Secretary of the Interior. This centralizing of information has proved of great benefit.

The meeting of the governors with the President last May has been held by many to be the greatest single event of the Roosevelt administration. It now receives its logical development in the meeting planned for next month in which questions of national economics will be expanded to include those involving international coöperation. The citizens of three nations will realize that after all, their industries and interests are practically the same; that hitherto destructive rather than preservative tendencies in dealing with natural resources have been shown and especially that the force is only genuinely preservative if it includes the legitimate use of all resources and thereby creates enduring profit, replacing the temporary profits, which in some cases must cease with the extinction of the resources.

SPECIAL MESSAGE FROM THE PRESIDENT ON CONSERVATION

President Roosevelt sent a special message to Congress on January 22, concerning the report of the national conservation commission. He urged action by congress for the preservation and development of the resources of the country, and characterized the report as being "One of the most fundamentally important documents ever laid before the American people." He called attention to the fact that it contains the first inventory of natural resources ever made by any nation, and urges that the facts set forth in this report are an imperative call to action; the conditions they disclose demand that we shall concentrate an effective part of our attention upon the great natural foundations of national existence, progress and prosperity. He said:

The inventory is an irrefutable proof that the conservation of our resources is a fundamental question before this nation, and that our first and greatest task is to begin to live within our means.

The first of all considerations is the permanent welfare of our people; and true moral welfare, the highest form of welfare, cannot permanently exist save on a firm and lasting foundation of material well-being. In this respect our situation is far from satisfactory. After every possible allowance has been made, and when every hopeful indication has been given its full weight, the facts still give reason for grave concern.

It would be unworthy of our history and our intelligence and disastrous to our future to shut our eyes to these facts or attempt to laugh them out of court. The people should and will rightly demand that the great fundamental questions shall be given attention by their representatives. I do not advise hasty or ill-considered action on disputed points, but I do urge, where the facts are known, where the public interest is clear, that neither indifference and inertia, nor adverse private interests, shall be allowed to stand in the way of the public good."

The President recommended that the plan for the development of water ways recommended by the Inland Water Ways Commis-

sion be put in effect without delay, and urged that provision be made for the protection and more rapid development of the National forests.

NEW YORK STATE WATER WAYS ASSOCIATION

The New York State Water Ways Association held a two-days conference in Brooklyn on January 21 and 22. The conference closed with the resolution asking Congress to establish a national department of public works with a secretary who should be a member of the President's Cabinet.

Another resolution urged the officials of the city of New York to be doubly sensitive to anything that might tend to injure the manufacturing interests. The city was also asked never to permit the discontinuance of ferry traffic between the two boroughs.

Norman B. Fish, of Tonowanda, speaking of the Erie Canal, said that Canada had spent $150,000,000 on a water transportation system to divert traffic which should pass through New York.

Congressman Joseph E. Randall said that the appropriations by Congress for deep waterways was altogether too meager.

SOUTH DAKOTA

The conservation commission of South Dakota, in a preliminary report recommended the following measures for the conservation of the soil, water resources, forests and coal.

(1) Conservation of the soil.

Make the wilful waste of the fertility of the soil a public offense with heavy penalties.

Provide for the education of the people upon the most approved methods of agriculture, having in view the preservation of the fertility of the soil, in the public schools, in farmers' institutes and through the public press.

Encourage the application of dry farming methods in agriculture, through the experimental stations and in the farmers' institutes.

(2) Conservation of the water resources.

By strict regulation of the boring, flow and use of the artesian waters.

By impounding the flood waters in draws and valleys.

(3) Preservation of our natural forests and encouragement of forestry.

Our natural forests are chiefly within the natural forest reserves, and are receiving the careful attention of the national government. Such forests as are so protected should be carefully guarded by the laws of the state and especially should there be enforced rigorous penalties for the setting of forest fires. Tree planting should be encouraged by every proper means.

(4) Preservation of the coal mines for the use of the people.

Prompt action should be taken by the state and nation to prevent the coal measures of the state from passing into the hands of private monopolies, and such regulations be adopted as will preserve the great gift of nature for the benefit of the public.

VERMONT

The Legislature of Vermont has passed a bill appointing a forestry commission. The commission will consist of five members, including the Governor of the State and the director of the experiment station. The members of the commission will serve without pay, but a salaried State forester will be appointed. The commission may accept or buy waste land for forestry purposes.

AVIATION

The French Government, through M. Barthou, Minister of Public Works, offers 100,000 francs for the encouragement of aërial locomotion, the government reserving the right to decide how the money shall be spent.

M. Barthou is of the opinion that open spaces should be provided by the government for the use of the aëronauts.

THE PRESENT STATUS OF MILITARY AËRONAUTICS

The War Department has issued the paper on Aëronautics by Maj. George O. Squier, of the U. S. A. Signal Corps, presented at our Annual meeting, 1908, in separate form for the use of officers interested in the subject. It is considered the most up-to-date and comprehensive treatment of the dirigible, the free balloon and the heavier-than-air machine that has been written.

Technical Colleges

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BANQUET

The Massachusetts Institute of Technology held their annual banquet in Boston, January 14, 1909. Addresses were made by Governor Eben S. Draper, of Massachusetts, a member of the Class of '78; Acting President Arthur A. Noyes, Class of '86; the President-Elect Richard C. Maclaurin and Dr. R. S. Woodward, of the Carnegie Institute of Washington.

Dr. Maclaurin spoke about the desirability of removing the Institute to a place which would allow its development to continue. Governor Draper spoke of the Institute problems, and their solution under the guidance of the coming administration. Dr. Noyes gave a brief account of the recent work of the Institute, and Dr. Woodward emphasized the value of coöperation and mutual support.

Mr. Edwin S. Webster, of the Class of '86, a member of the firm of Stone & Webster, of Boston, was elected President of the Alumni Association for the ensuing year.

UNIVERSITY OF MICHIGAN

The new engineering building of the University of Michigan is to have an addition in the form of a wing, 60 ft. wide, 130 ft. long and four stories high.

Land for a summer camp for the civil engineering students has been presented to the University by Col. and Mrs. Charles C. Bogardus of Pellston, Mich. The tract contains 1500 acres in Cheboygan County, with nearly three miles of shore line upon Douglas Lake.

A new reflecting telescope is to be added to the equipment of the observatory.

THE MECHANICAL ENGINEERING DEPARTMENT OF COLUMBIA

The graduates and former students of the Engineering Department of Columbia University dined together on January 16. All the classes since 1901 were represented among the thirty-five men present.

Dean Goetze was a guest, and spoke briefly upon the merits of the organization, assuring the society of his coöperation and assistance. Professor Lucke also spoke, outlining the possibilities of the society, and emphasizing the importance of an inter-communication bureau of the members.

PERSONAL

Mr. O. G. Bennet, who was until recently connected with the American Trading Co., Kobe, Japan, has severed his connection with that company and will spend several months in traveling.

Mr. James M. Brown, for two years with the Casey & Hedges Co., Chattanooga, Tenn., is at present with the Lyons Boiler Works, De Pere, Wis., in the capacity of Superintendent.

Mr. Harry M. Chamberlain, formerly of Dorchester Center, Mass., has accepted a position with J. W. Buzzell, Civil and Mechanical Engineer, The Tribune Building, New York.

Mr. George William Cole, formerly with Westinghouse-Church-Kerr & Co., has accepted a position as Secretary of The Economic Engineering Co., 50 Church St., New York.

Mr. Claude E. Cox is now located with the Interstate Automobile Co., Muncie, Ind., as Chief Engineer and Factory Manager.

Mr. Edward R. Feicht has entered the service of the American Beet Sugar Co., as Master Mechanic of the Lamar Factory, Lamar, Colo.

Mr. Burton P. Flory, connected with the Central Railroad of New Jersey for several years, has been appointed Superintendent of Motive Power Department of the Ontario and Western Railroad.

Prof. W. F. M. Goss, Dean of the College of Engineering, and Prof. L. P. Breckenridge, Professor of Mechanical Engineering of the University of Illinois, were the guests of honor at an informal luncheon given by a number of graduates of the University, at the Duquesne Club, in December. Both Professors Goss and Breckenridge are acting in an advisory capacity in connection with the United States Geological Survey Testing Plant at Allegheny Arsenal. Professor Breckenridge is Vice-President of the Society.

Mr. Morris A. Hall is no longer connected with Mack Bros. Motor Car Co., Allentown, Pa. He is at present on the staff of The Automobile, 231 W. 39th St., New York.

Mr. Walter L. Hill, recently connected with the Eastern Cold Storage Co., Boston, Mass., as Treasurer, is at present a partner of the firm Hill-Ray Engineering Co., with offices at 110 State St., Boston, Mass.

Mr. David T. Jones, has been transferred to the Pottstown, Pa., office of the Wilbraham-Green Blower Co. He was formerly located at the Philadelphia office of this company, in the same capacity, Treasurer and General Manager.

Mr. Dermot McEvoy has recently been engaged by the Revere Rubber Co., Chelsea, Mass. Mr. McEvoy was formerly associated with the Derby Rubber Co., Derby, Conn., as Vice-President and General Manager.

Mr. Charles H. Repath, formerly with the Anaconda Copper Mining Co., Anaconda, Mont., as Mechanical Superintendent, has entered the employ of the International Smelting and Refrigerating Co., Salt Lake City, Utah, in the capacity of Superintendent of Construction.

Mr. William N. Ryerson, who until recently was Superintendent of The Ontario Power Co. of Niagara Falls, has accepted a position with The Great Northern Power Co., Duluth, Minn., as General Manager.

Mr. John V. Schaefer, who has been associated with the Roberts & Schaefer Co., Chicago, Ill., as President, is now connected with the Schaefer Manufacturing Co., Birmingham, Ala., in the same capacity.

Mr. W. H. Smead, who has lately been connected with the Proximity Manufacturing Co.'s Mills, Greensboro, N. C., has opened an engineering office at 302 McAdoo Building, Greensboro, N. C. He will make a specialty of designing steam power and heating plants.

Mr. Thomas J. Walsh is no longer in the employ of the Woonsocket Electric Machine and Power Co., Woonsocket, R. I. He has accepted a position with the Tampa Electric Co., Tampa, Florida.

Mr. Edward C. Wells, formerly Manager of the Quincy Engine Works, Quincy, Ill., has accepted a position with the Hardie-Tynes Manufacturing Co. as Superintendent.

Mr. Thomas D. West has issued a pamphlet on Accidents, Their Causes and Remedies, setting forth the reasons for the greater percentage of accidents occurring in this country than in any other, and offering suggestions for remedies calculated to prevent them.

NECROLOGY

GEORGE W. CORBIN

George W. Corbin was born in New Britain, Conn., March 3, 1859. He attended the local schools and Wilbraham Academy until 18 years of age. His first business connection was with P. & F. Corbin, who later organized the Corbin Cabinet Lock Company, making Mr. Corbin manager, and later secretary and president. He resigned to become president of the Union Manufacturing Company, and held this position until his death, November 30, 1908. He organized several other manufacturing corporations, and took an active part in municipal affairs—the savings banks, local government and schools.

He was connected with several social orders, among them being the Masonic order, in which he had received the thirty-third degree, and numerous social clubs.

WARREN E. HILL

Warren E. Hill was born in New York in 1835. In 1852 he entered the service of the Allaire Iron Works in Newark, N. J., and was associated with that company for six years. In 1858 he was appointed superintendent in charge of the installation of the Detroit (Mich.) water works, which position he held until 1862, when he returned to the East and accepted a position with the Continental Iron Works of Brooklyn. In 1888 he was made vice-president, and in 1907 president of this firm, the position he held at the time of his death. Mr. Hill was the designer of the machinery and engines of the original "Monitor," which defeated the "Merrimac" in Hampton Roads.

His death occurred in New York, December 8, 1908. He became a member of this Society in 1884.

RICHARD HERMAN SOULE

Richard Herman Soule was born March 4, 1849, in Boston, Mass. September 25, 1875, he entered the service of the Pennsylvania Railroad, where he remained for eight years. He held this position for

two years until promoted to the test department. Two years later, in 1879, he was made superintendent of motive power of the Northern Central Railway.

In 1881 and June 1882, he was superintendent of motive power of the Philadelphia and Erie division of the Pennsylvania Railroad, and in June 1882 accepted a position in the same capacity with the Pittsburg, Cincinnati and St. Louis Railway.

In 1883, when the West Shore Railway enterprise was carried through, its managers secured the best talent available in the country for their managing officers, and Mr. Soule was appointed superintendent of motive power, a position which he held until the absorption of the West Shore Line by the New York Central in 1887. From February 1887, to April 1888, he was general manager of the New York, Lake Erie and Western Railroad, and in November 1888, he was appointed general agent of the Union Switch and Signal Co. He was engaged in the introduction of modern interlocking and lock-signaling plants until 1891. From 1891 to 1897 he was superintendent of motive power of the Norfolk and Western Railroad, and did much to put the rolling-stock of the system, which was then coming into prominence as an important coal-carrying road, on a thoroughly sound basis.

For the next two years, Mr. Soule was in the employ of the Baldwin Locomotive Works, spending nearly a year traveling in foreign countries. He had charge of the Chicago office of this company for a year and a half.

In 1900 he opened an office in New York as a consulting mechanical engineer and practiced until, on account of ill health, he was forced to retire from active business.

Mr. Soule was a member of the Master Car-Builders Association; and author of a report on the standards of this association, which led to a radical change in the association's practice, and to a placing of the standards on a much higher basis. He was also a member of the American Railway Master Mechanics Association. He was one of the managers of this Society, 1898–1901.

He was universally respected and esteemed for his many sterling qualities, which caused his acquaintance to be highly prized by his associates. In all parts of the country men are found who testify to the help given them early in life by Mr. Soule, to whom they owe much of their later success. His memory will live long in the hearts of those to whom he had endeared himself.

Mr. Soule's death occurred at his residence in Brookline, Mass., December 13, 1908.

THOMAS GRAY

Dr. Thomas Gray, Vice-President and Professor of Dynamic and Electrical Engineering of Rose Polytechnic Institute, Terre Haute, Ind., died December 19, 1908.

He was born in Fifeshire, Scotland, February 2, 1850. He took a course in engineering at the University of Glasgow, Scotland, where he graduated in 1878 with the degree of B.S. Later he took a four-year course in practical physics and telegraph engineering under Sir William Thomson (Lord Kelvin).

He was engaged by the Japanese government as instructor in telegraph engineering at the Imperial College of Engineering at Tokio, Japan. After this engagement he was employed by Sir William Thomson and Professor Fleming Jenkin, engineers of the Commercial Cable Co., to superintend the manufacture and the laying of that Company's system of transatlantic and other cables, and had sole charge under them, as resident engineer, of the whole of that work. He was later chief assistant to Lord Kelvin in his engineering work.

In 1888, he was appointed to the professorship at Rose Polytechnic Institute, and held the position until his death.

Doctor Gray was the author of Directions for Seismological Observations, in the British Admiralty Manual of Scientific Inquiry; of articles on telephones and telegraphs in the Encyclopædia Britannica, and of the Smithsonian Physical Tables. He also wrote many papers on scientific and technical subjects, and was engaged as an expert in electricity on the staff of the Century Dictionary.

SOCIETY HISTORY

Chapter VIII

THE WORLD'S FAIR AND THE ENGINEERING CONGRESS

198 At the New York Meeting, held in December 1892, the committee of the Society having in charge the participation of the American Society of Mechanical Engineers in the conduct of the Mechanical Section of the Engineering Congress, to be held at the Columbian Exhibition, reported that the work had been organized by making the officers of Division B of the Congress identical with the officers of the Society. It was announced that the sessions were to be held from July 31 to August 5, 1893, in the Art Palace on the Lake Front in Chicago, the Congress to be opened and closed with general sessions of all the sections, and the intermediate period to be utilized for the special sessions in the different sections in various portions of the building. Under this arrangement papers presented before the Congress relating to mechanical-engineering subjects were to form a portion of the proceedings of the Section, whether by members of The American Society of Mechanical Engineers or by others, the entire proceedings and discussions forming a portion of the published Transactions of the Society.

199 The Committee reported also that the Society had entered definitely into the plan for the maintenance of a joint engineering headquarters in the city of Chicago, thus joining in the plan for the reception and entertainment of visiting engineers from other parts of the world.

200 Other important reports presented at the New York Meeting of 1892 were those upon the testing of steam engines and other machines at the Columbian Exposition, upon flange standardization, and upon the desirability of a standard system for the thickness of metallic plates.

201 The address of the retiring President, Commodore Charles H. Loring, was devoted to the subject of the influence of the steam engine upon modern civilization, showing the enormous influence

which this single product of the engineer had exerted upon the conduct of the world.

202 A number of important papers were presented at this meeting of the Society, among which may be mentioned an analysis of the shaft governor, by Mr. F. M. Rites, setting forth the applications of the inertia principle since so extensively applied to automatic steam engines; a discussion of steam boiler explosions, following the presentation of a paper upon an explosion at Worcester, by Mr. F. H. Daniels, and a very animated discussion upon the subject of the proper qualifications entitling a man to be called an engineer.

203 During this meeting the interest of the members in the approaching exposition was most evident, and the results of the gatherings in Chicago bore out in a most gratifying manner the success which attended the effective preliminary work of the officers, committees, and interested members who realized the importance of the occasion. At this meeting of the Society Mr. Eckley B. Coxe, of Drifton, Penna., was elected President, to serve for the ensuing year.

204 Prior to the gathering of the members for the Engineering Congress at Chicago at the close of July 1893, it became evident that the meeting was to be largely attended and that it was destined to be a great success. Visiting engineers from England, France, Germany, Austria and other countries arrived in New York, either in parties, or individually, and all were received and greeted by the local members, and everything done that was possible to make them realize that the members of the Society appreciated the opportunity which was being offered to return in some degree the hospitalities which had been extended to its members when abroad. The registration at the headquarters at Chicago bore out these indications, the roll including 283 members, besides a large number of guests, including engineers from England, and the British colonies, from France, Belgium, Germany, Austria, Italy, Sweden, Norway, Russia, Japan and South America.

205 Although it was evident that the work of the Congress would naturally occupy most of the time allotted for the convention, it was not forgotten that the meeting was a regular meeting of the Society, and that it should include some of the social features which had become established at such gatherings. The presence of the Exposition offered the great entertainment in itself, but through the effective work of local members some especial opportunities were afforded including a trip to a number of the engineering features of the Exposition, including the construction work of the Exhibition

buildings, the intramural electric railway and its power house, the traveling platform, the extension work upon the Chicago water-works tunnel, and a number of the mechanical portions of individual exhibits not otherwise wholly open to visitors.

206 On the morning of July 31, there was gathered in the Memorial Art Palace a remarkable body of engineers, including large representations from the memberships of the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Mining Engineers, and of engineers devoted to military, marine and naval engineering, and to engineering education. In this gathering were included eminent specialists from all parts of the world, men whose names were familiar in the professions and the constructive arts; men upon the results of whose labors depended the manufactures, commerce and industries of civilized countries, who controlled transportation by land and by water, and in whose hands lay the maintenance of peace and the control of national defense. To this assemblage there was made an effective address of welcome by President H. C. Bonney, of the Congress Auxiliary Committee, and after fitting responses from the various delegations there represented, the several sections separated to their assigned meeting rooms for organization and discussion.

207 Following the regular business of the Society, including reports of committees, tellers of election, etc., the effective business of the Congress was begun by the reading and discussion of papers. It is not practicable nor is it desirable to give here any critical analysis of the contributions to the applied science of engineering as presented at this memorable international gathering. It is necessary only to glance at the portly volume of the Transactions of The American Society of Mechanical Engineers for 1893, to realize by its unusual size the extent to which the opportunity was grasped to lay before the assembled members of the profession the latest developments of mechanical engineering. To that volume the interested engineer must be referred for details, and in this place some endeavor will be made to show the important character of the work of the Society as a whole, and its relation to the developments which have followed.

208 One of the most important subjects, measured either by the number of papers or by their relations to subsequent developments was that of locomotive engineering. To this question were devoted papers by Prof. W. F. M. Goss, M. A. Mallet, of Paris, Mr. A. Von Borries, of Hanover, Mr. Albert Schneider, of Brunswick, and

the committee of the Society upon standard methods of conducting locomotive tests. The extent to which these papers and their discussions have influenced subsequent work in their respective lines will be seen when it is perceived that they included studies of locomotive testing apparatus, such as was originally installed at Purdue University, and led to the plant now used by the Pennsylvania Railroad Company at Altoona; the use of articulated locomotives of the Mallet type for maximum tractive power under difficult conditions, since widely employed on both sides of the Atlantic; together with fruitful discussions upon compounding for locomotive engines, and the practical use of rack railways for mountain roads.

209 The subject of steam engineering naturally came in for abundant attention during the Congress. Thus, Professor Dwelshauvers-Dery, of Liége, honorary member of the Society, presented a discussion of the theory of the steam engine, while Mr. Charles T. Porter, honorary member of the Society, discussed the limitations of engine speed, showing the importance of the increase of clearance losses with increased rotative speed. When this paper is taken in connection with that of Mr. Frank H. Ball, upon the fallacy of the assumption that high compression can neutralize clearance losses, it will be seen that some of the essential features of the important discussion of ten years later by Dwelshauvers, Boulvin, Isherwood and others were anticipated. Reports of tests upon pumping engines and upon railway power plants furnished valuable contemporary records, while the posthumous paper of Prof. James H. Fitts referred to the possibilities of the evaporative condenser in a manner which has since been practically realized.

210 Apart from the groups of papers thus referred to, mention may be made of certain isolated communications to the Congress, such as the exhaustive discussion of technical education in the United States, by Dr. R. H. Thurston, upon haulage by horses, by Mr. Thomas H. Brigg, an arraignment of the ordinary defective methods of harnessing draught horses; and upon the development of interchangeable systems of manufacture, by Mr. W. F. Durfee. An interesting anticipation of a comparatively recent development appears in the paper by Herr Pieper, of Hamburg, upon the taximeter for recording fares in public vehicles.

211 A valuable feature of the Congress was the report of the Committee upon Standard Methods of Testing Materials, the secretary of this committee, Mr. G. C. Henning, having attended the conference of the German Union at Vienna in May. The result of

this report was the endorsement by the Congress of the efforts to establish a uniform international system of testing materials.

212 The papers themselves formed but a portion of the real benefit to the profession gained by the participation in the Engineering Congress. At such a gathering the interchange of personal experiences and the opportunity of widening the scope of professional acquaintances is greatly multiplied over the possibilities at an ordinary convention. The Exposition itself formed a remarkable record of the work of the engineer in all departments of effort, and it was possible, within the limits of its grounds, to see much of the best work of the men who themselves were present at the sessions of the Congress. That the close connection of the Society with engineering work at the Exposition was a real stimulus to its growth, was felt by all who had the privilege and opportunity of attending either the Congress or the Exposition or both.

213 The beneficial influence of the activity in connection with the Columbian Exposition was by no means limited to those members who were able to visit Chicago. By far the greater portion of the foreign visitors passed through New York City, and arrangements had been made to extend the use of the house in Thirty-first Street to all who might come; while a special local Committee formed of members of the Council held itself ready to assist in receiving the visitors.

214 Unfortunately it was not found practicable for members of the British engineering societies to visit America in a body, and hence no concerted welcome could be given to them comparable with that which had been given to the American engineers who had visited England four years before. It was therefore possible only to receive the members of the Institution of Civil Engineers and kindred societies individually as they arrived and passed through New York on their way to Chicago, and such opportunities were seized and utilized whenever possible. The French Engineers, however, found it practicable to organize a party of about fifty members of the Société des Ingénieurs Civils de France, who, leaving Havre on August 26, 1893, arrived in New York on September 3, too late to participate in the Engineering Congress, but in ample time to see the Exposition at its best, and to receive the welcome of their former guests from the United States.

215 This party of French engineers, under the guidance of the Marquis de Chasseloup-Laubat, himself a member of the French Society as well as of the French Commission to the Columbia Expo-

sition, had arranged to spend some time in various American cities. Members of The American Society of Mechanical Engineers were at the pier to receive the visitors, and the utmost was done to show them the attractions of New York City during the four days of their stay, while a committee accompanied them on a special train to Chicago, via Niagara Falls. Before returning to New York, the French engineers visited St. Louis, Pittsburgh, Washington, and Philadelphia, and in each of these cities they were received and entertained by members of the Society.

216 At the Annual Meeting of the Society, held in New York in December 1893, it was possible to report upon the entire success of the work of the Society in connection with the Engineering Congress and the World's Fair, and to record the completion of all the business connected with the additional undertaking which it had thus accepted.

OFFSETTING CYLINDERS IN SINGLE-ACTING ENGINES

By Prof. Thurston M. Phetteplace, Providence, R. I.
Member of the Society

A great deal has been said recently about the offsetting of cylinders in single-acting engines and many claims of superiority are made by those who employ this form of construction.

2 About twenty-five manufacturing establishments in the United States are building engines in which the cylinders are offset, chiefly those of the automobile type, and one company is formed for the purpose of making engines in which the offset is equal to the crank radius and the connecting rod length is about $3\frac{3}{8}$ times the crank radius.

3 Among the claims made by manufacturers for offset engines are: greater power, less side-pressure of the piston on the walls of the cylinder, better turning effort, less vibration, smoother running qualities, and when one cam shaft is used, a more convenient mechanical arrangement.

4 On account of the importance of this subject and the lack of information concerning it, a complete discussion is desirable and is here presented.

5 The cylinder of an engine is said to be offset when its center-line is not in a plane through the center of the crank shaft. The practice is not new and is applied to both steam and gas engines having one or any number of cylinders.

6 In the diagram, Fig. 1, AB represents the stroke, OE the crank radius, DE the connecting rod, θ the crank angle, and OC the offset. It should be noticed that θ is the angle the crank makes with a line through the center of the crank shaft parallel to the center-line of the

The full development of the mathematical formulae of this paper, with some other related matter, is given in an unpublished Appendix, which is on file in the Library of the Society for the use of members who wish to verify the mathematical work.

To be presented before The American Society of Mechanical Engineers. All papers are subject to revision.

cylinder, and not the actual angle passed over from the inner dead point. The length of the stroke is

$$AB = R\sqrt{(a+1)^2 - k^2} - \sqrt{(a-1)^2 - k^2}$$

which is greater than $2R$.

R = crank radius.
a = L/R.
L = connecting rod length.
k = offset divided by R.

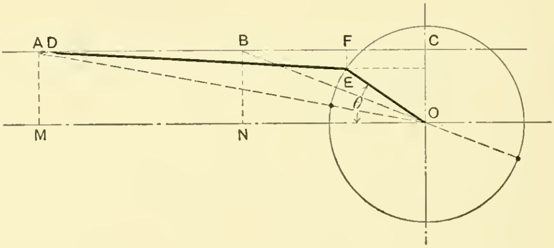


FIG. 1 DIAGRAM OF CRANK AND CONNECTING ROD TRAIN

Thus for 3 in. crank radius the strokes would be as shown in Table 1 The distance to the end of the stroke farther away from the center of the crank shaft is shortened, thus OM is less than $DE + EO$ or $L + R$ which affects the height of the engine.

TABLE 1

Ratio L/R	Offset R	Stroke	Increase Per cent
Any	zero	6.00000	0.00
3	0.10	6.00375	0.06
3	1.00	6.42279	7.04
4	1.00	6.21180	3.50
5	1.00	6.12930	2.15
6	1.00	6.08730	1.01

7 The dead points are not opposite each other, so that the crank angle swept over while the piston makes the out-stroke is less than that for the in-stroke, causing a quick return motion and an average velocity for the in-stroke or compression and exhaust strokes greater than for the out-stroke, or explosion and suction strokes.

8 An expression for the piston position in terms of the crank angle θ is developed in the usual way and is

$$X/R = \sqrt{(a+1)^2 - k^2} - \cos\theta - \sqrt{a^2 - (k\text{-}\sin\theta)^2}$$

in which X = the piston displacement from the end of the stroke farther from the crank shaft.

9 The force of inertia due to the reciprocating parts is equal to the weight multiplied by the acceleration divided by 32.2. The value for the acceleration is found by differentiating the expression for the piston displacement twice with respect to the time. This is done by expanding the radical $\sqrt{a^2 - (k - \sin\theta)^2}$ by the binomial theorem, into a convergent series and then dropping all terms containing a with a negative exponent of 3 or larger in order to get an expression that can be easily differentiated. This gives

$$(a^2 - (k - \sin)^2)^{\frac{1}{2}} = a - \tfrac{1}{2} a^{-1} k^2 + a^{-1} k \sin\theta - \tfrac{1}{2} a^{-1} \sin^2\theta$$

This approximate expression for the radical differs from the radical for different values of k, a and θ, as shown in Table 2.

TABLE 2 DIFFERENCE BETWEEN EXACT AND APPROXIMATE EXPRESSIONS

k	a	θ	$\sqrt{a^2 - (k - \sin\theta)^2}$	$a - \frac{1}{2}a^{-1}k^2 + a^{-1}k\sin\theta - \frac{1}{2}a^{-1}\sin^2\theta$	Difference
1	6	90	6.000000	6.000000	zero
1	6	0	5.916079	5.916666	+.000587
1	6	45	5.992762	5.992867	+.000105
.5	6	90	5.979130	5.979166	+.000036
.5	6	0	5.979130	5.979166	+.000036
.5	6	45	5.996428	5.996429	+.000001
.5	3	90	2.958039	2.958333	+.000294
.5	3	0	2.958039	2.958333	+.000294
.5	3	45	2.992849	2.992859	+.000010
.5	4½	90	4.472136	4.472222	+.000086
.5	4½	0	4.472136	4.472222	+.000086
.5	4½	45	4.495236	4.495239	+.000003

10 The greatest difference has no significant figure until the fourth decimal place is reached and this is when $k = 1$, which is an unusual value. Hence it is readily seen that the error introduced by this approximate form is slight.

11 Substituting this value of the radical in the expression for the piston displacement and differentiating twice with respect to the time gives

$$F/A = 0.00034\, W/A\, N^2R\, (a^{-1} k \sin\theta + \cos\theta + a^{-1}\cos 2\theta)$$

which is the expression for the inertia force per square inch of piston head area when there is an offset.

A = area of piston head.
W = weight of the reciprocating parts.
N = revolutions per minute.
R = crank radius in feet.

This differs from the similar expression when there is no offset by the addition of the term $a^{-1}k \sin \theta$, so that tables for inertia factors for no offset may be used by adding the value of this term.

12 The expression for the tangential pressure or the turning force for any offset is

$$T = P\left(\sin\theta + \cos\theta \frac{\sin\theta - k}{a - \frac{1}{2}a^{-1}k^2 + a^{-1}k\sin\theta - \frac{1}{2}a^{-1}\sin^2\theta}\right)$$

in which P is the pressure on the piston pin in the direction of the center of the cylinder. This is a long expression to solve and a graphical solution may be followed if preferred. The work of solving the expressions for inertia force and tangential pressure may be somewhat lessened by tabulating the quantity $a^{-1}k \sin \theta$ which appears in these expressions.

13 The derivation of the preceding formulae and tables is shown in the appendix.

SIDE PRESSURE OF PISTON ON CYLINDER WALLS

14 A reduction of the side pressure of the piston on the cylinder walls is one of the advantages claimed for offsetting.

15 There are two ways in which the side pressure may affect the single-acting engine: (*a*) The maximum value of the side pressure determines the length of piston to keep the maximum pressure per square inch of projected area below a value which is assumed as not too great to destroy the oil film between the rubbing surfaces; (*b*) The average value of the side pressure produces the friction between the sliding surfaces causing a mechanical loss and some wear of the parts. The loss in mechanical efficiency is more important than the wear, especially in the small high-speed automobile engines.

16 The average side pressures may be found by adding all of the areas between the axis and the curve of side pressures and dividing by the total length, or the areas themselves may be taken for comparison, as they represent the work done on the side of the cylinder

by the piston, which is lost work and should be kept as low as possible. Curves of side pressures of the piston on the cylinder walls were constructed, it being necessary (*a*) to assume a gas card, (*b*) to assume engine dimensions, (*c*) to calculate inertia forces and plot curves,

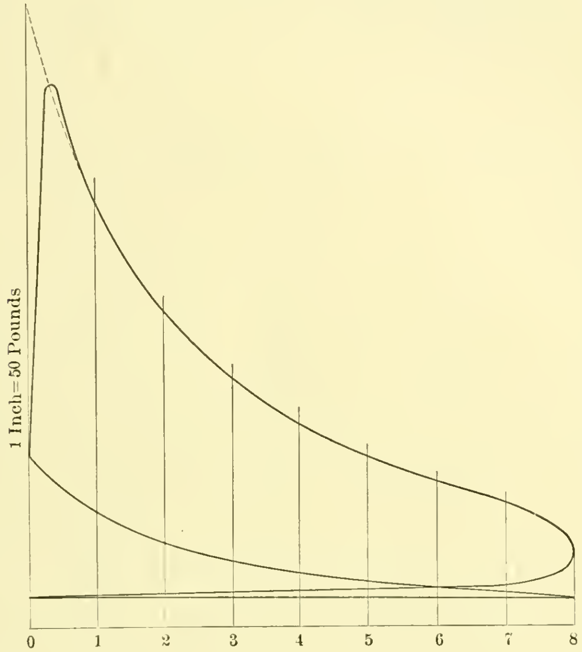


Fig. 2 Offsetting Cylinders in Single-Acting Engines

Gasolene Card Compression, 70 lb.; Maximum Pressure, 259 lb.; Pressure ratio, 3.77

(*d*) to combine inertia forces with gas pressures, obtaining the force at the piston pin, and then (*e*) to determine the side pressure component perpendicular to the center-line of the cylinder for the changing angularity of the connecting rod. The gasolene card chosen is shown in Fig. 2. As it seemed desirable to investigate two similar cases, one

TABLE 3

Specifications	Slow	High
R.p.m.	450	1500
W/A	1 lb.	0.70 lb.
R	6 in. = 0.5 ft.	$2\frac{1}{2}$ in. = 0.208 ft.
0.00034 $W/A\ N^2R$	34.4	111.38

for high speed and the other for slow speed, the dimensions given in Table 3 were chosen.

TABLE 4 PISTON POSITION FACTORS

CALCULATED BY THE FORMULA

$$X/R = \sqrt{(a+1)^2 - k^2} - \cos\theta - a + \tfrac{1}{2}a^{-1}k^2 - a^{-1}k\sin\theta + \tfrac{1}{2}a^{-1}\sin^2\theta$$

FROM BEGINNING OF STROKE TOWARDS THE CRANK SHAFT. MULTIPLY BY CRANK RADIUS TO FIND PISTON POSITION. (NOTE: CRANK RADIUS IS NOT ONE-HALF OF THE STROKE)

Crank Angle	$L \div R = 3$		$L \div R = 4\frac{1}{2}$	
	Offset = 0.30 R	Offset = 0.50 R	Offset = 0.30 R	Offset = 0.50 R
4°18′	0	.....	.....	.....
7°11′	.....	0	.....	.....
3°7′	.....	.....	0	.....
5°13′	.....	.....	.....	0
15	0.023	0.012	0.026	0.018
30	0.129	0.103	0.130	0.111
45	0.309	0.269	0.303	0.275
60	0.525	0.491	0.527	0.492
75	0.804	0.746	0.782	0.742
90	1.070	1.010	1.046	1.005
105	1.321	1.263	1.299	1.26
120	1.525	1.491	1.527	1.49
135	1.723	1.683	1.717	1.69
150	1.861	1.835	1.862	1.84
165	1.955	1.944	1.958	1.95
180	2.0037	2.0102	2.0018	2.0049
188°38′	2.0114	......	......	......
194°29′	......	2.0321	......	......
184°55′	......	......	2.0047	......
188°13′	......	......	......	2.0131
195	2.0065	2.0303	1.992	2.007
210	1.961	2.001	1.929	1.954
225	1.865	1.918	1.810	1.846
240	1.699	1.779	1.643	1.684
255	1.515	1.585	1.429	1.475
270	1.270	1.343	1.179	1.227
285	0.997	1.068	0.911	0.957
300	0.699	0.779	0.643	0.684
315	0.471	0.504	0.407	0.432
330	0.229	0.269	0.197	0.222
345	0.075	0.098	0.061	0.075
360	0.0037	0.0102	0.0018	0.0049

17 The piston position factors and inertia factors are given in Tables 4 and 5, and Fig. 3 to Fig. 8 give the curves of inertia forces.

The full lines represent the slow-speed and the mixed lines the high-speed cases. Inertia curves and side-pressure curves were plotted for ratios of L/R of $4\frac{1}{2}$ and 3, and for offsets of zero, $0.30\,R$, and $0.50\,R$ for both high and slow speeds, making twelve cases in all. When there is an offset the inertia curve must be plotted for 360 deg. instead of 180, since for the return stroke it is not the reverse of that for the forward stroke, as is the case when there is no offset.

TABLE 5 INERTIA FACTORS

Calculated by Formula $(a^{-1}k \sin\theta + \cos\theta + a^{-1}\cos 2\theta)$

Angle	$L/R = 3$		$L/R = 3\frac{1}{2}$	$L/R = 4$	$L/R = 4\frac{1}{2}$		
	$K = 0.30$	$K = 0.50$	$K = 0.20$	$K = 0.30$	$K = 0.30$	$K = 0.40$	$K = 0.50$
15	1.280	1.297	1.229	1.200	1.175	1.181	1.187
30	1.083	1.116	1.037	1.028	1.010	1.021	1.033
45	.778	.825	.747	.760	.754	.769	.785
60	.419	.477	.406	.440	.447	.465	.485
75	.067	.131	.066	.104	.131	.152	.174
90	−.233	−.166	−.229	−.175	−.156	−.134	−.111
105	−.450	−.386	−.451	−.404	−.385	−.364	−.344
120	−.580	−.523	−.594	−.560	−.553	−.535	−.515
135	−.636	−.589	−.666	−.654	−.660	−.645	−.629
150	−.650	−.617	−.695	−.704	−.722	−.711	−.699
165	−.653	−.635	−.703	−.731	−.757	−.751	−.745
180	−.667	−.667	−.714	−.750	−.778	−.778	−.777
195	−.703	−.721	−.733	−.769	−.791	−.797	−.803
210	−.750	−.783	−.752	−.778	−.788	−.799	−.810
225	−.778	−.825	−.747	−.760	−.754	−.769	−.785
240	−.753	−.811	−.692	−.690	−.669	−.687	−.707
255	−.644	−.708	−.561	−.548	−.513	−.534	−.556
270	−.433	−.500	−.343	−.325	−.288	−.310	−.333
285	−.127	−.191	−.044	−.040	.003	.018	−.040
300	.246	.189	.308	.310	.331	.313	.293
315	.636	.589	.667	.654	.660	.545	.629
330	.983	.950	.981	.954	.944	.933	.917
345	1.228	1.211	1.199	1.164	1.141	1.135	1.129
360	1.333	1.333	1.286	1.250	1.222	1.222	1.222

18 Comparing Fig. 3 with Fig. 6 a slight hump is noticed at the right-hand side in the former but not in the latter. This is probably due to error in the formula, for the small value of L/R since the force could not be higher near the end of the stroke than at the end.

19 The general effect of offsetting on the inertia curve is shown in Fig. 9, where the curves for $L/R = 3$, offsets = zero and $0.50\,R$, are compared, the curve for no offset being in full lines.

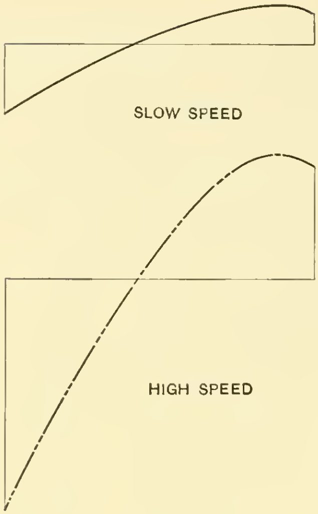


Fig. 3

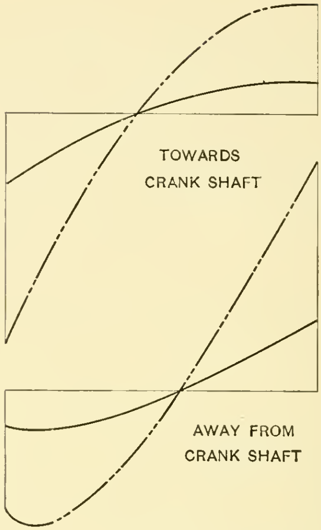


Fig. 4 Offset = 0.30 R.

Curves of Inertia Forces on Piston Position Base

Slow Speed: r.p.m. = 450; R = 6; $\frac{W}{A}$ = 1 lb.; L ÷ R = 3.

High Speed: r.p.m. = 1500; R = $2\frac{1}{2}$ in.; $\frac{W}{A}$ = 0.7 lb.; L ÷ R = 3. Offset zero.

Full Lines, Slow Speed; Mixed Lines, High Speed.

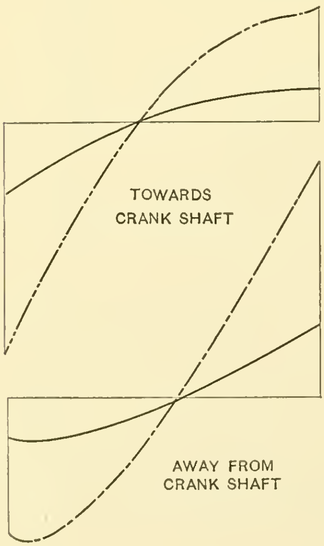


Fig. 5 L ÷ R = 3. Offset = 0.50 R.

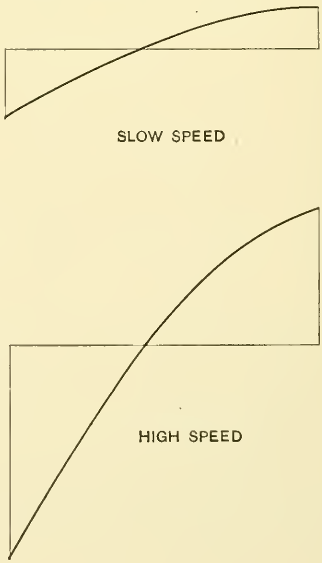


Fig. 6 L ÷ R = $4\frac{1}{2}$. Offset = zero.

Curves of Inertia Forces on Piston Position Base

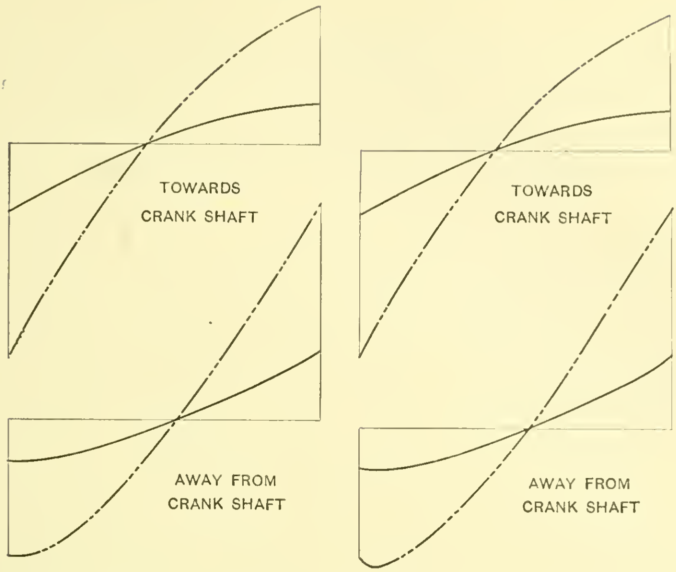


FIG. 7 $L \div R = 4\frac{1}{2}$. Offset = 0.30 R. FIG. 8 $L \div R = 4\frac{1}{2}$. Offset = 0.50 R

CURVES OF INERTIA FORCES ON PISTON POSITION BASE

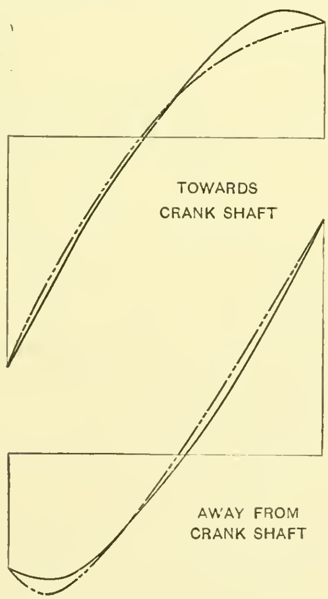


FIG. 9 INERTIA FORCE CURVES SHOWING EFFECT OF OFFSETTING

$L \div R = 3$, High Speed. Full Lines, Offset = Zero; Mixed Lines, Offset = 0.50 R

20 The curve for an offset is a little flatter near the end of the out stroke and the hump is increased near the beginning of the return stroke, which is probably due to inaccuracy in the formula.

21 The curves of side-pressures are shown in Fig. 10 to 15. The maximum side-pressure, its cause (whether combined gas and inertia pressure or inertia force alone) and its location are given in Table 6.

TABLE 6

Ratio L/R	Offset	Max. side-pressure		Due to		Stroke	
		Slow	High	Slow	High	Slow	High
$4\frac{1}{2}$	0	25	26	Gas	Gas	1	1
$4\frac{1}{2}$	$0.30\,R$	17	24	Gas	Inertia	1	2
$4\frac{1}{2}$	$0.50\,R$	12	28	Gas	Inertia	1	2
3	0	$35\frac{1}{2}$	45	Gas	Gas	1	1
3	$0.30\,R$	23	39	Gas	Inertia	1	2
3	$0.50\,R$	20	51	Inertia	Inertia	2	2

22 From this for $L/R = 4\frac{1}{2}$, slow-speed, maximum pressure is lowest with 0.50 R offset, and if the offset were further increased the maximum side-pressure would probably not be reduced as the values at the beginning of the second and fourth strokes would increase, and now they are already 11 so that any increase would soon cause an increase in the maximum value instead of a decrease. In the case of $L/R = 3$ the lowest maximum value occurs when the offset is 0.50 R, but in this case it is possible that the offset is already a trifle large, as the maximum value occurs at the beginning of the second stroke, although it is not much greater than that in the first stroke, being 20 in the former case and 18 in the latter. Hence for the slow speed the best offset would seem to be about 0.50 R as far as the maximum value of side-pressure is concerned.

23 In the case of $L/R = 4\frac{1}{2}$, high speed, the maximum side-pressure due to inertia force at the beginning of the second stroke seems to increase with the amount of offset, while the maximum value due to the gas pressure in the first stroke seems to decrease with the increase in offset. These values are shown in Table 7. $L/R = 4\frac{1}{2}$.

TABLE 7

Offset		Zero	$0.30\,R$	$0.50\,R$
Side pressures due to.........	Gas pressure, 1st stroke...	26	17	13
	Inertia, 2d stroke.........	15	24	28

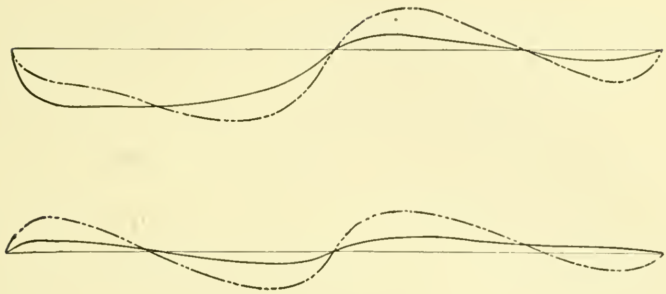


Fig. 10 Curve of Side Pressures on Piston Position Base
C ÷ R = 3, No Offset. Full Lines, Slow Speed; Mixed Lines, High Speed

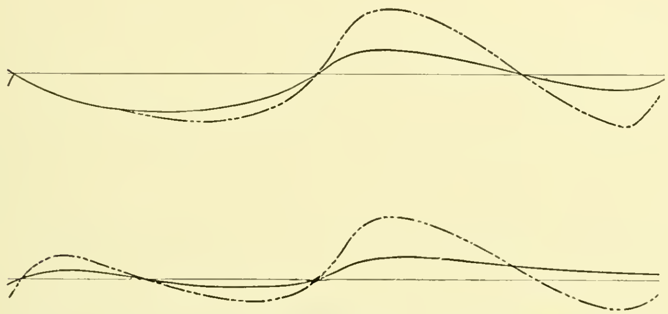


Fig. 11 Curve of Side Pressures on Piston Position Base
L ÷ R = 3, Offset = 0.30 R. Full Lines, Slow Speed; Mixed Lines, High Speed

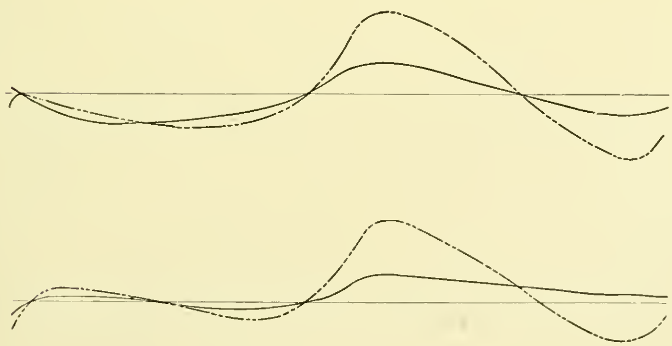


Fig. 12 Curve of Side Pressures on Piston Position Base
L ÷ R = 3, Offset = 0.50 R. Full Lines, Slow Speed; Mixed Lines, High Speed

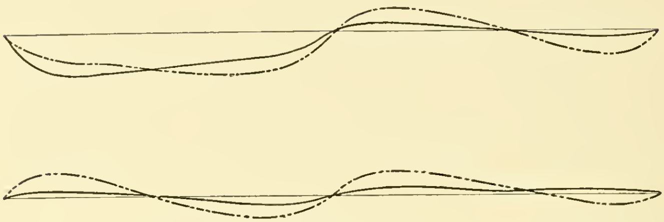


Fig. 13 Curve of Side Pressures on Piston Position Base

L ÷ R = 4½, Offset = Zero. Full Lines, Slow Speed; Mixed Lines, High Speed

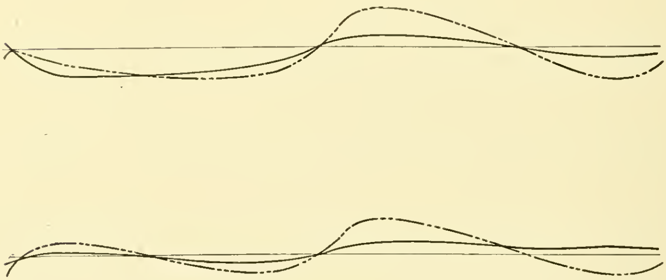


Fig. 14 Curve of Side Pressures on Piston Position Base

L ÷ R = 4½, Offset = 0.30 R. Full Lines, Slow Speed; Mixed Lines, High Speed

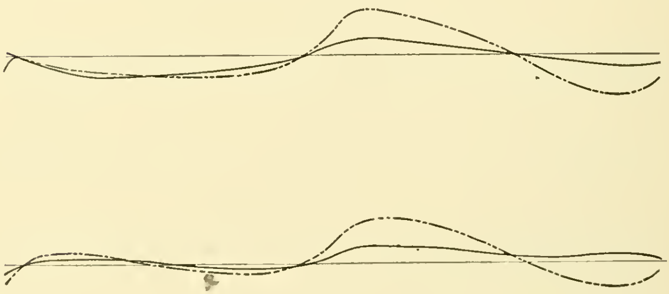


Fig. 15 Curve of Side Pressure on Piston Position Base

L ÷ R = 4½, Offset = 0.50 R. Full Lines, Slow Speed; Mixed Lines, High Speed

24 Plotting curves of these values, the most favorable offset as far as maximum side-pressure is concerned is 0.16 R when $L/R = 4\frac{1}{2}$. This curve is shown in Fig. 16.

25 See Table 8 for values $L/R = 3$. This would place the best offset for $L/R = 3$, as far as maximum side-pressure is concerned,

TABLE 8

Offset		Zero	0.30 R	0.50 R
Side pressures due to.........	Gas pressure, 1st stroke...	45	30	20
	Inertia, 2d stroke.........	25	39	51

as 0.20 R, which would seem to indicate that a greater offset would be desirable as the ratio L/R decreased. It remains to determine if possible the best offset as far as the work done in side-pressure is concerned.

26 The work done is proportional to the areas included between the axis and the curve of side-pressures. It seems to make no difference whether a larger amount of work is done on one side than on the other, or in other words there seems to be no advantage in having the work done on each side the same, unless at some time it might be desired to rebore the cylinder, in which case wear occurring all on one side might have left the walls too thin or might necessitate the removal of much more metal.

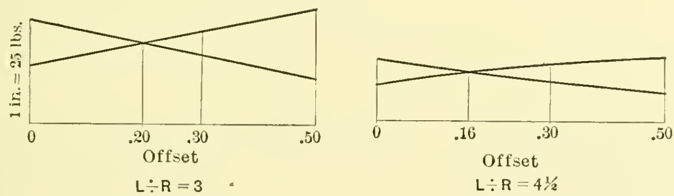


FIG. 16 CURVE SHOWING VARIATION OF SIDE PRESSURE WITH OFFSET

27 Table 9 shows the results of measuring the areas, namely the ratio of work done in one case to that in each of the other cases, and also the actual average side-pressures. For the *slow-speed* case there seems to be a decrease of work done on one side, and an increase of work done on the other side, resulting in a decrease in the total work done with the offset, which would indicate that the greater the offset, the less the loss in work. The average side-pressure also decreases with the offset, although it is less with no offset when $L/R = 4\frac{1}{2}$ than with 0.50 R offset when $L/R = 3$.

28 In the case of the *high speed* the areas on one side decrease with the offset while those on the other side increase, but the totals for $L/R = 4\frac{1}{2}$ decrease and then increase, while for $L/R = 3$ they con-

TABLE 9

Ratio L/R	Offset	SLOW SPEED				HIGH SPEED			
		+Area	−Area	Total Area	Average Side Pressure	+Area	−Area	Total Area	Average Side Pressure
$4\frac{1}{2}$	0	1.61	− .53	2.14	6.6	2.33	−1.11	3.44	10.7
$4\frac{1}{2}$	0.30 R	1.09	− .90	1.99	6.2	1.78	−1.58	3.36	10.5
$4\frac{1}{2}$	0.50 R	0.74	− .93	1.67	5.2	1.62	−1.90	3.52	11.
3	0	2.59	− .92	3.51	11.	4.11	−1.45	5.56	17.3
3	0.30 R	1.55	−1.15	2.70	8.4	3.01	−2.76	5.77	18.0
3	0.50 R	1.11	−1.39	2.50	7.8	2.47	−3.40	5.87	18.3

tinue to increase, and of course the same is true for the mean side-pressure.

29 This would seem to indicate that there is little if anything to be gained by an offset in regard to work done by the piston on the walls of the cylinder when the inertia force is very high, since what is gained on one side is more than made up in loss on the other side.

30 If it is of sufficient importance to have the work done on each side of the cylinder the same, we may plot curves of the work done on each side and note where they intersect, as in Fig. 17 . In the case of the slow speed we would have the work done on each side equal when the offset was about 0.40 R and in the high speed this point would be about 0.36 R.

31 *Thermal Cycle.* Offsetting increases the length of stroke, which gives increased expansion to the gas, and increases the piston velocity on the in-stroke, giving greater inertia to the gas on the exhaust and reducing the amount of leakage by the piston on the compression stroke. This refers to the 4-cycle gas engine.

32 *Lubrication.* The curves of side-pressure show the manner in which the side-pressure changes sides, which is a good thing for lubrication. This changing sides would be about the same for offset or no-offset except in the case when the offset is equal to the crank radius. Here the pressure is almost continually on one side of the cylinder so that oil would with difficulty be introduced between the surfaces. Other things being even, except for this extreme case, the reduction in amount of side-pressure should make lubrication more satisfactory.

33 *Vibration and Balance.* Revolving masses and reciprocating masses may cause vibration in gas engines. Offsetting the cylinders would not affect the revolving masses at all but does change the curves of inertia forces, as already shown in Fig. 3 to 8. These inertia-force diagrams are now combined in different ways according to different arrangements of cylinders, and are compared with similar curves when there is no offset.

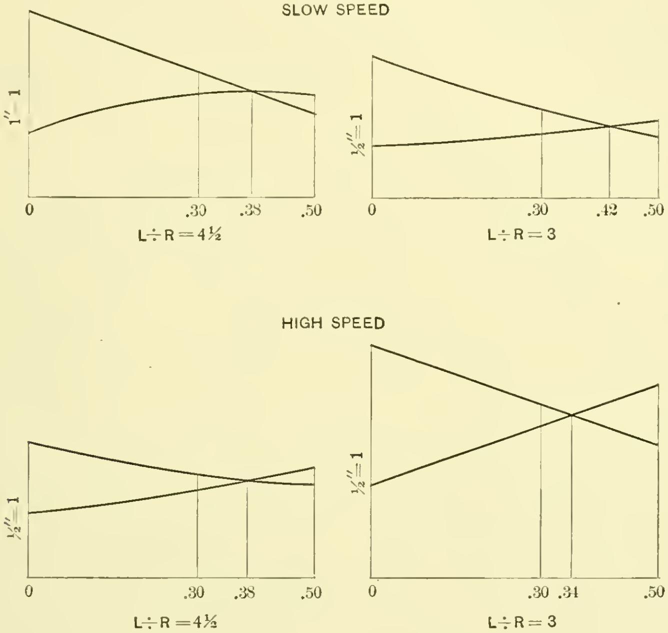


FIG. 17 CURVES SHOWING OFFSET WHEN WORK IS SAME ON EACH SIDE OF CYLINDER

34 The following discussion applies only to the 4-cycle type of gas engine, whose arrangements are:

- *a* Single cylinder.
- *b* Two-cylinder vertical.
- *c* Two-cylinder opposed.
- *d* Three-cylinder vertical.
- *e* Four-cylinder vertical.
- *f* Four-cylinder double-opposed.
- *g* Six-cylinder vertical.

35 For this comparison the high speed case, when $L/R = 4\frac{1}{2}$, was chosen, the offset being equal to zero and one-half the crank radius.

36 Fig. 18 shows the inertia curves for a single-cylinder engine. These curves must be shown for 360 deg. of crank angle, for they differ on the return and forward strokes. The curves for no-offset are shown in full lines and for 0.50 R offset in dotted lines. The difference between the two curves is apparent.

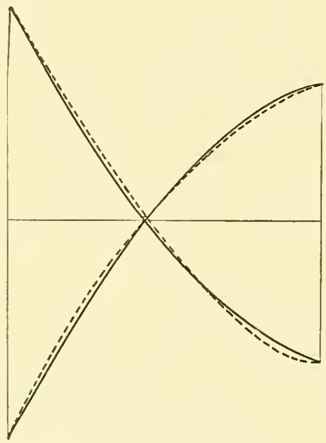


Fig. 18 Curves of Inertia Forces on Piston Position Base

L ÷ R = 4½. Full Line, Offset = Zero; Dotted Line, Offset = 0.50 R. High Speed Case

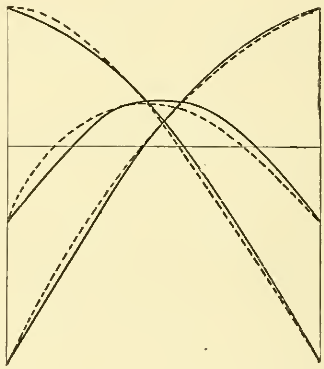


Fig. 19 Curves of Free Unbalanced Inertia Forces. Two Cylinder Vertical Engine

L ÷ R = 4½; Full Line, Offset = Zero; Dotted Line, Offset = 0.50 R. High Speed Case

37 Fig. 19 shows the curve of free inertia forces for a two-cylinder vertical arrangement. These curves are not so very different; the one for an offset being nearly the same as the other but moved along a little instead of being symmetrical with a center line perpendicular to the axis. The maximum values of the forces are about the same. The vibrations when there is an offset would have unequal periods but about the same amplitudes. For the four-cylinder vertical case the ordinates of these curves could be doubled and the same general difference would exist.

38 In the case of the two-cylinder opposed motor with cranks at 180 deg., the inertia forces would be balanced whether the cylinders were offset or not, but in the case of an offset a new couple in

a plane perpendicular to the axis would be introduced due wholly to the offsetting, which cannot be balanced. The couple in an axial plane due to the cylinders being not in line would be the same, offset or not, but with an offset there would be added another couple in this plane due to the offset, which would not be balanced.

39 In the case of a four-cylinder double-opposed motor the forces would be balanced and also the couples in an axial plane, but the couples in the plane perpendicular to the axis would be doubled while those in the axial plane due to the offset would be balanced.

40 The case of a three-cylinder vertical arrangement can be discussed by considering the formula for the inertia forces,

$$F/A = 0.00034\ W/A\ N^2R\ (a^{-1}k \sin\theta + \cos\theta + a^{-1}\cos 2\theta)$$

Let the cranks be at 120 deg.; then the crank angles will be θ, $\theta + 120$, and $\theta + 240$. Substituting these values in the formula, the part in brackets reduces to zero, showing that the inertia-forces are balanced. However, the moments resulting from these forces are not balanced. By placing two three-cylinder vertical engines together so that the two middle cranks are in the same plane the six-cylinder engine is obtained, in which the inertia forces and couples are both balanced.

41 From this discussion it follows that offsetting the cylinders has no effect on the vibration due to the reciprocating parts, except in the case of the 2-cylinder opposed and 4-cylinder double-opposed arrangements of cylinders. In these cases the offsetting increases the unbalanced inertia-force couples by adding new ones.

42 Vibration may be felt from the irregularity of the turning-effort curves, which for four different cases are shown in Fig. 22. There is such a slight difference here that it can be neglected, especially since the turning-effort curve depends so directly on the shape of the gas card, which may vary considerably. The conclusion in regard to vibration would be that offsetting does not affect the vibration appreciably except in the case of a two-cylinder opposed or a four-cylinder double-opposed motor.

GENERAL CONCLUSIONS

43 The following are perfectly general conclusions, to be followed by a more definite comparison of actual engines.

a The length of stroke for a given crank radius increases as the offset increases.

b The length of stroke for a given crank radius for any offset decreases as the ratio of L/R increases.

c The increase in length of stroke causes an increase in average piston speed.

d Offsetting the cylinders makes the crank and connecting rod train a quick return mechanism.

e When the cylinders are offset the crank passes over an angle greater than 180 deg. during the out-stroke of the piston, and less than 180 deg. during the in-stroke.

f The average velocity of the piston is greater on the exhaust and compression than on the explosion and suction strokes.

g Offsetting the cylinders reduces the angularity of the connecting rod on the out-stroke and increases it on the in-stroke.

h When there is an offset, the side-pressure of the piston on the cylinder walls does not change sides at the end of the stroke, but just after the beginning and just before the end of the out-stroke.

i The place where this change of side-pressure occurs approaches the middle of the stroke as the amount of offset approaches the crank radius.

j With no offset, high inertia forces do not greatly increase the maximum side-pressure during the explosion stroke, but do increase it considerably, during all of the other strokes, and this effect is slightly greater as the ratio of L/R decreases.

k With no offset the work done increases with the inertia-force and as the ratio of L/R decreases.

l For low inertia forces, as far as the maximum value of side-pressure is concerned the best offset is one-half the crank radius.

m Considering the maximum value of the side-pressure only, the most favorable value for the offset decreases as the inertia-forces increase, for any ratio of L/R, but does not decrease as rapidly, for smaller values of the ratio L/R.

n For low inertia forces, the work done by the piston on the cylinder walls decreases as the offset increases, but of course is greater for smaller values of L/R.

o For very high inertia forces, the work done decreases slightly with the offset up to 0.40 of the crank radius for value of $L/R = 4\frac{1}{2}$.

p For very high inertia forces, and small values of L/R, there is no advantage in an offset, as far as the work done by the piston on the cylinder walls is concerned.

q The thermal cycle is slightly benefited by offsetting and the benefit increases with the amount of offset.

r Lubrication should be slightly improved by offsetting the cylinders.

s Vibration due to the free inertia forces is no different except in the case of a two-cylinder opposed or four-cylinder double-opposed motor.

44 Table 10 gives data of gas engines that have been constructed and put in operation. The average crank radius is about $2\frac{1}{2}$ in., the

TABLE 10 DATA OF GAS ENGINES HAVING CYLINDERS OFFSET

No.	*R* Crank Radius	*L* Length of Connecting Rod	Ratio L/R	Offset Amount	Offset Per cent	Length of Piston	Diam. of Bore	Ratio Piston Length to Diameter
1	7	$23\frac{5}{8}$	3.37	7	100	14	9.47	1.47
2	$2\frac{9}{16}$	$8\frac{15}{16}$	3.48	$\frac{5}{8}$	24.	6	$5\frac{1}{2}$	1.09
3	$2\frac{1}{4}$	$8\frac{1}{2}$	3.77	$\frac{3}{8}$	16.6	6	4	1.5
4	$2\frac{1}{2}$	$9\frac{1}{2}$	3.8	$\frac{3}{8}$	15	$5\frac{5}{8}$	5	1.125
5	$2\frac{1}{2}$	10	4.0	$\frac{3}{8}$	15	$6\frac{1}{2}$	$4\frac{3}{4}$	1.37
6	3	$12\frac{1}{4}$	4.08	$\frac{9}{16}$	18.75	$5\frac{5}{8}$	....	....
7	$2\frac{3}{8}$	$9\frac{3}{4}$	4.1	$\frac{1}{2}$	21	$5\frac{3}{8}$	5	1.075
8	$2\frac{1}{2}$	$10\frac{1}{2}$	4.2	$\frac{7}{8}$	35	$5\frac{7}{32}$	$4\frac{3}{4}$	1.098
9	$2\frac{3}{4}$	12	4.36	$\frac{15}{16}$	34	$6\frac{3}{4}$	$5\frac{1}{4}$	1.28
10	$2\frac{1}{4}$	$10\frac{1}{2}$	4.36	$\frac{7}{8}$	38	$5\frac{1}{2}$	$4\frac{1}{4}$	1.29
11	$2\frac{1}{2}$	12	4.8	1	40	6	$4\frac{3}{4}$	1.26
12	$2\frac{1}{2}$	12	4.8	1	40	$6\frac{1}{4}$	5	1.25
13	$2\frac{1}{2}$	12	4.8	1	40	6	$4\frac{3}{4}$	1.26
14	$2\frac{1}{2}$	....	....	$1\frac{1}{4}$	50	....	....	....
15	$2\frac{3}{4}$	....	....	$1\frac{1}{8}$	40	....	....	....
16	3	....	....	1	33	....	....	...
17	$2\frac{1}{2}$	....	....	$\frac{3}{4}$	30	....	....	....

Westinghouse standard engine has an offset of 50 per cent of crank radius.

ratio of L/R varies from 3.48 to 4.8 and the percentage of offset varies from 15 to 50. The average diameter of cylinder-bore is 4.81 in. and the average ratio of length of piston to diameter is 1.24.

45 For comparison of engines the following dimensions were taken:

Crank radius	= $2\frac{1}{2}$ in.
Diameter of bore	= $4\frac{3}{4}$ in.
R.p.m.	= 1000

Weight of reciprocating parts per square inch of piston head area = 0.6 lb.

Ratios of $L/R = 3\frac{1}{2}$, 4, and $4\frac{1}{2}$ and an offset, for each of the values of L/R, the largest amount practicable. These offsets are:

$L/R = 4\frac{1}{2}$	Offset = zero
" $= 4\frac{1}{2}$	" $= 0.40\ R$
" $= 4\frac{1}{2}$	" $= 0.30\ R$
" $= 3\frac{1}{2}$	" $= 0.20$ R

46 Tables were prepared for each of the above cases, and values calculated for crank angles varying by increments of 15 deg. each. Each of these tables contained values for the crank angle, piston position factor, the actual piston position, the gas pressure, inertia factor, inertia force, piston pin pressure, tangential factor, and the turning force from which the inertia curves and turning effort curves were plotted.

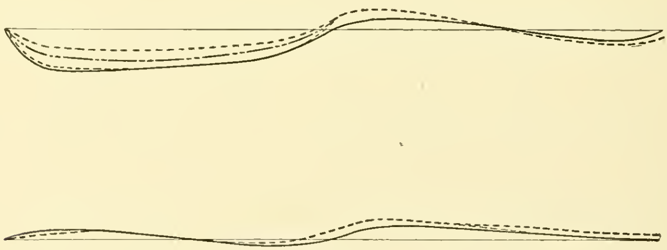


Fig. 20 Curve of Side Pressures on Piston Position Base

R.p.m. = 1000; $\frac{W}{A}$ = 0.60 lb. R = $2\frac{1}{2}$ in. Full Line, L ÷ R = $4\frac{1}{2}$; Offset = Zero Broken Line, L ÷ R = $4\frac{1}{2}$; Offset = 0.40 R. Mixed Line, L ÷ R = 4; Offset = 0.30 R. Dotted Line, L ÷ R = $3\frac{1}{2}$; Offset = 0.20 R.

47 Careful comparison of the curves in Fig. 20 will show a slight difference between them, but not enough to warrant the trouble of plotting them separately for use in connection with the gas pressures to find the piston-pin forces from which the side-pressures are determined.

48 The inertia forces shown in Fig. 20 were combined with the gas pressures and the curves of side-pressures plotted as before, with the results shown in Fig. 21.

49 The maximum values for the side-pressure were determined and the areas representing the work done by the piston on the cylinder

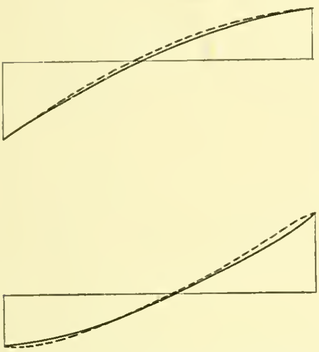


Fig. 21 Curves of Inertia Forces on Piston Position Base

R.p.m. = 1000;

R = $2\frac{1}{2}$ in.; $\frac{W}{A}$ = 0.60 lb.

1 L ÷ R = $4\frac{1}{2}$ Offset = Zero
2 L ÷ R = $4\frac{1}{2}$ Offset = 0.40 R
3 L ÷ R = 4 Offset = 0.30 R
4 L ÷ R = $3\frac{1}{2}$ Offset = 0.20 R

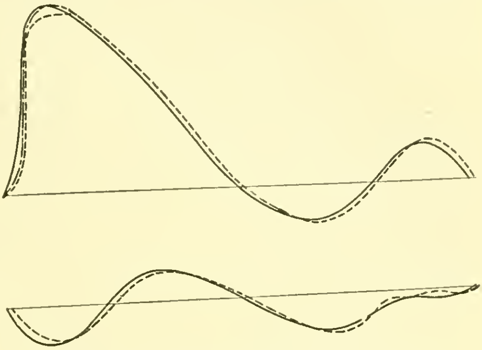


Fig. 22 Turning Effort Curves on Crank Angle Base

Full Line, L ÷ R = $4\frac{1}{2}$ Offset = Zero
Mixed Line, L ÷ R = $3\frac{1}{2}$ Offset = 0.20 R
Dotted Line, L ÷ R = $4\frac{1}{2}$ Offset = 0.40 R
Broken Line, L ÷ R = 4 Offset = 0.30 R

walls were carefully measured and recorded (see Table 11). As far as these quantities are concerned, the best value is $L/R = 4\frac{1}{2}$, offset = 0.40 R. The turning-effort curves (shown in Fig. 22) are so nearly alike that the difference is hardly worth mentioning.

TABLE 11

L/R	Offset	Max. Side Pressure		Work Done in Area Units		
		One Side	Other Side	One Side	Other Side	Total
$4\frac{1}{2}$	zero	24	7	1.55	0.60	2.15
$4\frac{1}{2}$	0.40	12	12	0.93	0.87	1.80
4	0.30	17	12	1.17	0.82	1.99
$3\frac{1}{2}$	0.20	23	12	1.53	0.81	2.54

50 Table 12 gives a comparison of the four cases chosen. This table explains itself, but a short discussion may bring out the important points more clearly.

51 There is a slight increase in the length of stroke, but less than one-half of one per cent, so that it amounts to very little. The angle passed over by the crank during the out-stroke is slightly greater than 180 deg. and the greatest gain is 1.7 per cent, which is small. The first great difference occurs in the length of connecting rod, No. 4 effecting a saving of 2.50 in. or 22.2 per cent.

52 Referring to the next line, the distance from the center of the crank-shaft to the position of the center of the piston pin at the end of the stroke, is a measure of the height of the engine and shows a decrease corresponding to the value of L/R.

53 The maximum side-pressure decreases with the offset and increases with the decrease in value of the ratio L/R, so the best case would be No. 2, where L/R is largest and the offset is also largest. Here a reduction of 50 per cent is gained, which reduced the necessary length of the piston 44 per cent. No. 4 is the worst case, L/R very small and the offset also small and then the side-pressure is a trifle less than it is with no offset. The maximum value of the side-pressure affects the length of the piston and consequently the height of the engine, and the length of the cylinder, and so the weight of the cylinder and engine, and the weight of the piston and the corresponding weight of the reciprocating parts, and so the inertia force. The length of the piston is reduced 43.7 per cent in No. 2, 24.4 per cent, in No. 3 and 3.6 per cent in No. 4. The ratio of length of piston to diameter is rather small in No. 2 but is not unusual in the other cases.

54 If it is not desired to take advantage of the maximum value of the side-pressure by reducing the length of the piston, it can be made 1.20 times the diameter, a usual value as is seen in Table 10, which would reduce the pressure per square inch of projected area and so increase the chances of satisfactory lubrication. The reduction of this pressure per square inch of projected area is shown in the next row.

55 In order to find the exact resulting height of the cylinder up to the top of the piston at the end of the in-stroke it is necessary to calculate the position of the piston pin in the piston. This is done in the next row, by making the sums of the products of the areas with the distance from the piston pin center to their centers balance on each side of the piston pin. In case No. 2, with $L/R = 4\frac{1}{2}$, a 50 per cent offset might have been used without interference and this would give better results than 0.40 R offset, but in case No. 4, 0.20 R is undoubtedly about as much as could be used although it would be desirable to use more if a very low engine were wished for.

TABLE 12 COMPARISON OF ACTUAL ENGINES

Specifications	No. 1	No. 2	Gain	No. 3	Gain	No. 4	Gain
Diameter of Bore	$2\frac{1}{2}$	$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{1}{2}$	
Crank Radius	$4\frac{3}{4}$	$4\frac{3}{4}$		$4\frac{3}{4}$		$4\frac{3}{4}$	
R.p.m.	1000	1000		1000		1000	
W/A	.60	.60		.60		.60	
Ratio L/R	$4\frac{1}{2}$	$4\frac{1}{2}$		4		$3\frac{1}{2}$	
Offset	zero	.40 R		.30 R		.20 R	
Length of Stroke	5.000	5.021	0.42%	5.015	0.30%	5.009	0.18%
Crank Angle passed over, Stroke toward Crank Shaft	180°	182.4°	1.30%	183.08°	1.7%	182.03°	1.1%
Crank Angle passed over, Stroke away from Crank Shaft	180°	177.6°		176.92		177.97°	
Length of Connecting Rod	11.25 in.	11.25 in.		10.0 in.	1.25	8.75 in.	2.50 in.
Distance, Center of Crank, Shaft to end of Stroke	13.75 in.	13.693 in.	.057 in. 0.41%	12.477 in.	1.273 in. 9.2	11.239 in.	2.51 in. 18.2%
Maximum Side Pressure — One Side	24	12	50%	17	29%	23	4.19%
Maximum Side Pressure — Other Side	7	12		12		12	
Piston Length; 15 lb. per sq. in. proj. area; $\frac{7}{8}$ in. for rings, etc.	6.85 in.	3.86 in.	2.99 in. 43.7%	5.18 in.	1.67 in. 24.4%	6.60 in.	.25 in. 3.6%
Ratio: Piston Length to Diam.	1.44	.81		1.09		1.39	
Pressure per sq. in. proj. area Piston Length = 1.2 diam = 5.7 in	15.7	7.8	50%	11.3	28.1%	15.0	4.45%
Distance: Piston Pin to back end of piston	3.10 in.	1.68 in.		2.29 in.		2.98 in	
Distance: Crank Shaft to end of piston, end of in-stroke	17.5 in.	15.87 in.	1.63 in. 9.3%	15.36 in.	2.14 in. 12.2%	14.86 in.	2.64 in. 15.1%
Length of cylinder, end of piston in-stroke to other end of piston out-stroke	11.85	8.88 in.	2.97 in. 25.1%	10.19 in.	1.66 in. 14%	11.61 in.	.24 in. 2.0%
Work done by Piston on side of Cylinder, square inches	2.15	1.80	.35 16.6%	1.99	.16 7.4%	2.54	−.39 −18.1%
Average side-pressure	6.4	5.6		6.2		7.9	

56 The next two rows show the distance from the center of the crank-shaft to the end of the piston at the end of the in-stroke, which is a measure of the height and the length of the cylinder and also of the weight of the cylinder. As regards the height a gain of 15 per cent may be had in No. 4. No. 2 gives the shortest cylinder, 25 per cent shorter than No. 1, while No. 4 gives one only 2 per cent. shorter. It must be borne in mind that these values are for 1000 r.p.m. and that the value of the maximum side-pressure will increase with the speed. However, the low value of the pressure per square inch of projected area, 15 lb., allows a considerable increase before a dangerous value is reached.

57 The total amount of lost work is shown in the next column. No. 2 gives the best value, a saving of 16 per cent, while No. 4 gives a loss of 18 per cent.

58 In working out a satisfactory solution it would seem that one of two predominating ideas should be followed. Either a very low engine should be aimed at in which everything is sacrificed to height, or else the important object is to reduce to a minimum the side-pressure and the work lost due to friction resulting from side-pressure.

59 In the first case, let $L/R = 3\frac{1}{2}$, offset as much as possible without interference, and a reduction in height of 13 to 15 per cent may be had. This means a reduction and a saving in weight of the connecting rod, cylinder, valve stems, exhaust pipes, inlet pipes, and piston. The actual saving in length in the case above is $2\frac{5}{8}$ in. There will be some increase in the work lost in friction due to the increased average pressure of the piston on the cylinder walls.

60 If a reduction in height is not of primary importance, then a ratio of $L/R = 4\frac{1}{2}$ and an offset of 0.40 R to 0.50 R would seem to give the best results. This gives a reduction in total height of 8 or 9 per cent, a reduction in piston length of 44 to 45 per cent, a reduction in cylinder length of about 20 per cent, and a saving in lost work of about 16 per cent. These reductions would cause a further reduction in weight of piston, weight of cylinder, weight of valve stems, weight of exhaust and inlet manifolds, and a reduction of inertia effects as well as an increased life to the piston, piston rings and cylinder. In this case it might not be desirable to take full advantage of the reduction in length of piston, making it less than the stroke because the oil hole in the side of the cylinder, if one were used, would be uncovered at one end of the stroke or the other.

61 In concluding this comparison, the most desirable offset seems to be as much as can be practically obtained with ratios of $L/R = 4$

and greater, with a decided gain over an engine with no offset for speeds less than 1400 to 1500 r.p.m. The subject may be summed up as follows:

Improvements due to offsetting, (1) in the thermal cycle, (2) in the mechanical arrangement, (3) in the turning effort curve, and (4) in lubrication, are very slight and may be neglected.

62 The real advantages are:

a A reduction of the frictional losses due to the pressure of the piston on the walls of the cylinder, resulting in a slight increase in mechanical efficiency and less wear of the piston, piston rings, and cylinder, and consequently longer life.

b A reduction of the maximum value of the side-pressure of the piston on the walls of the cylinder, allowing the use of shorter connecting rods, shorter pistons, and shorter cylinders, resulting in a shorter and lighter engine and in lower inertia-forces due to the reciprocating parts.

The most important of these advantages would be a considerable saving in weight.

63 The disadvantage of offsetting lies in the fact that the reductions in average side-pressure and maximum side-pressure grow less as the speed and inertia-force increase, so that for a speed of 1400 to 1500 r.p.m. there is either no reduction at all or an increase.

Principal Conclusions

64 Offsetting increases slightly the length of stroke and the crank angle passed over during the stroke toward the crank shaft.

65 The maximum value for the side-pressure of the piston on the cylinder walls decreases as the offset increases up to a value of one-half the crank radius for any ratio of L/R.

66 The work lost in friction due to the side-pressure of the piston on the cylinder walls decreases as the offset increases up to a value of 75 per cent of the crank radius.

67 Both the maximum value of the side-pressure and the work lost in friction increase as the value of the ratio L/R decreases.

68 Offsetting decreases the height and weight of the engine.

69 Offsetting increases the life of the cylinder and piston.

70 Offsetting improves the thermal cycle.

71 The turning-effort curves when the cylinders are offset differ but slightly from those for no-offset.

72 The advantages of offsetting as regards the maximum side-pressure and work lost may be zero or negative for high inertia-forces resulting from speeds of 1500 r.p.m. or more.

DISCUSSION

TRAINING WORKMEN IN HABITS OF INDUSTRY AND COÖPERATION

By H. L. Gantt, Published in The Journal for Mid-November

ABSTRACT OF PAPER

Until within a few years the mechanic was necessarily the source and conserver of industrial knowledge, and on him rested, therefore, the responsibility for training workmen.

With the advent of the scientifically educated engineer capable of substituting a scientific solution of problems for the empirical solution of the mechanic, the responsibility of training workers naturally shifts to his shoulders. It he accepts this responsibility, and bases training on the results of scientific investigation, the efficiency of the workman can be so greatly increased that the manufacturer can afford to give those that take advantage of this training compensation far in excess of that usually paid for similar work.

DISCUSSION

Dr. Alex. C. Humphreys. It has been said that Americans are interested in education only as they can coin it. It is apparent that the educational methods described in Mr. Gantt's able and instructive paper can be coined; but it is encouraging to see the stress laid by the author upon the ethical influence of the methods he describes; and I venture to believe that, if this system were generally introduced throughout the United States, the resulting moral uplift would attract more attention than the increase in dividend-earning capacity.

2 Mr. Gantt refers to the complaint often made as to the growing inefficiency of labor. The complaint is well-founded, but certainly the responsibility cannot rest upon the working class alone. What has been done to meet the demand for trained workers, men

and women, in connection with the radical changes introduced into our industries since the days of the old apprentice system? Some well-directed and successful, but isolated, schemes have been inaugurated. Considerable attention is now being paid to industrial education, and the methods of the author should receive careful attention in this connection, as a substitute for the old apprentice system practically discarded under modern industrial developments.

3 As a people, we are inclined to be superficial. This is true as to much of our educational work, and this system is certainly promising as a corrective. The masses are not to be delivered from the curse of superficiality by ethical arguments; there must be direct and personal influence. It is not only the right, but the duty of all, to make every fair effort to increase their efficiency as wage-earners. Mr. Gantt refers to a force not sufficiently recognized which tends to encourage the worker to acquire greater proficiency and capacity as an earner—the pleasure and pride experienced by the performer in work well done. This is a force we cannot afford to ignore.

4 Our youths are not sufficiently taught the all-important lesson of obedience. Too often liberty degenerates into license; especially is this noticeable in those coming from foreign lands where they have had to endure oppression. We may then well welcome any system which promises systematically to teach obedience to the employed, while keeping the employer constantly reminded that fair play is the price of loyal and efficient service.

5 In this country, we need practical educational methods far more than is generally realized. We flatter ourselves that we are a practical people. If so, why do we not systematically train the youth of both sexes in our public schools to be self-supporting or self-sustaining units of the community? Mr. Gantt advocates teaching the workman, at the same time, *how* and *to do*. A more valuable lesson could not be taught in a country where the people aim to govern themselves.

6 The high degree of efficiency developed by this system is due to the elimination of lost motion. As a people, high and low, not only are we handicapped by the lost motion so generally in evidence, but, in boasting of our smartness, nimbleness and readiness, we fail to recognize the lost motion so often involved in the hasty action and lack of foresight typical of our people.

7 I can well believe that the system advocated by Mr. Gantt can be introduced in many of the factories of the United States to the advantage of the owners and the country at large.

Mr. H. V. R. Scheel. This paper contains many statements which must seem to the practical man and the engineer but expressions of what has been known for a long time, although perhaps not fully realized. Many of them are almost axiomatic. I think no one can doubt that such a system of management must result in the greater efficiency of workmen, individually and collectively, and in the greater coöperation of workmen, foremen and managers, with the attendant economies.

2 The history of mechanical development shows that inventions and improvements by men of no great mental training were until very recently more numerous than by men with trained minds. A possible reason is that men of the former class were intimately acquainted with the operation of the machine; whereas the attention of the latter has been claimed by what they, at least, considered larger and more important matters. Our mechanical and industrial advance would have been more rapid had investigations of individual operations been made by men better fitted for the work. The best methods should have been determined and the workmen trained in those best methods with the spur of increased earnings.

3 Before the days of the corporation, the factory system and the highly specialized workman, a very large proportion of workmen worked for themselves, and since in the last analysis the main reason for action is self-interest those men worked more industriously, more intelligently and with less waste of all kinds than the present-day workman. A bonus determined in a scientifically correct manner seems to be the best appeal to an individual's self-interest: however, a scientific determination does not mean that the employer is entitled to more than his fair share of the savings made.

4 Under this system all the men are pushers to the limits set by the men responsible for quality. The gang bosses and foremen who were formerly drivers are now principally engaged in planning work and in handling extraordinary difficulties. Those of us who have seen these principles and methods in operation can testify to the correctness of these statements. We have seen men working no harder than before, but having been taught proper methods, accomplish results which make bonuses of 50 per cent on the former wages profitable for the owners. We have seen workmen, who without a trade have come to be considered and to consider themselves skilled workmen in a class as high as the trained mechanic. We have seen the removal of room mechanics, foremen, and even superintendents, when the workmen could no longer afford to permit the mistakes and neglects of these superiors to pass without protest.

Dr. Rudolf Roesler. My old motto, "Courage to the last," is almost the only excuse I can offer for taking a few minutes of your time, especially since my knowledge of your language is as yet unfortunately very poor. Without taking part in the discussion I would like to speak of some general facts which I think will have your interest.

2 In Europe, and especially in Germany, the greatest interest exists in the new ideas of economical organization and management in workshops, among which not least interesting are those of Mr. Fred W. Taylor. I think one important consideration is the belief that the new principles can help to weaken the *casus belli* for the struggle between capital and labor, to weaken the reasons for existence in continental Europe of Social Democrats and in America of Labor Unions, and to unite the workman and his employer by making their interests common. The following facts will illustrate this general interest:

3 The greatest German engineering society, the Verein deutscher Ingenieure, has resolved by almost unanimous vote of its branch societies to give a place to such questions in the columns of its well-known journal, Zeitschrift des Vereins deutscher Ingenieure; and a number of the most illustrious practical scientists and scientific practical men have promised to support this movement.

4 The tool machine works of Mr. Ludwig Loewe in Berlin is considered one of the best organized and managed factories of this kind. As much as is compatible with the German conditions this concern has been the first to take up the ideas which Mr. Gantt has explained. The book concerning the organization of the Ludwig Loewe Company by Mr. Lilienthal has proved the general interest by its wide circulation.

5 I come now to the most important because the most far-reaching fact. At the Technische Hochschule of Berlin in Charlottenburg there is a chair of Organization and Management, founded, I think, in 1 04. These principles among others are taught. According to the rules formed by the Prussian government and the Technische Hochschule, graduates in Mechanical Engineering, and I think also in Civil and Electrical Engineering, must take examinations in those two subjects. Thus every year as many as 1000 engineers go into the world with a knowledge of these principles.

6 I use advisedly the word Hochschule because there does not exist in English a term exactly analogous to the Hochschule; the American High School does not at all correspond to our Hochschule, which is the institution of the highest technical education in Germany.

7 In the case of each of the above-mentioned agencies, namely in

the scientific press, in the advanced machine shops and in our technical universities the matter of training workmen is considered of very great importance. In the Ludwig Loewe shop instruction cards and personal instruction by an engineer, in short, the fundamental ideas which Mr. Gantt has explained, are in common use. Also in the lectures at the Hochschule referred to, these matters are treated again and again.

8 I myself am astonished to see how many of the difficulties which seem to oppose the introduction and the continued application of those principles are removed in practice and how this system, based entirely on theoretical principles, can be adapted to the actual conditions. He who knows the system only by theory is not well able to judge it. These facts I have myself experienced. I was also astonished to see how Mr. Gantt has introduced his method with success into works whose daily product varies in form and character and in works other than machine shops.

9 I am sorry that I cannot illustrate by figures my remarks about the interest which the new ideas have for the men in European industries. The time between the moment when I was advised of Mr. Gantt's reading and the reading itself was not enough to get these statistics. I would be glad to give them to you later and then I hope with words more conforming to English grammar and pronunciation.

Mr. T. F. Kelly. Mr. Gantt's paper seems to me far too mild in its statements. My experience with the system for the last two years has been that every man in the plant, whatever his authority, has a specific job, and will get into trouble if he lays down on it. Under this system every employee becomes also an inspector, and for fear of losing his bonus protests vigorously against accepting material on which he has to work, unless both the material and former work are up to the standard for quality. It takes only a few touches on his pocketbook to make Mr. Jones a first-class critic on Mr. Brown; in other words, 300 employees means 300 inspectors.

2 The machinery must also be in first-class condition for operators to make their bonus. The "good enough" machinist cannot live under this system, as he not only loses his own bonus, but causes the gang-boss and the operator to lose theirs. These all act like a tonic on our Mr. Machinist, to do a good, quick job, or he soon finds out he is not the man.

3 The introduction of the bonus system is followed by a new feeling of pride, and the threat to move workmen from machines on

bonus to machines not on bonus is more effective than the threat to lay off or discharge.

4 The operators in our factory formerly measured their work to the clock; they now measure it to the task, and former shirkers are now among the most zealous of our employees. For instance, one of our weavers "suffered," and made our work suffer, through his disposition to malaria, but the bonus did more for his malady than any amount of quinine. On looking into the causes of an incipient riot the other day I found that our malarial friend had been trying to "beat up" a fellow workman who was not giving supplies fast enough and thereby keeping him out of his bonus.

Mr. C. H. Buckley. Of the many valuable features of this paper that of a definite plan drawn up for the task to be performed especially appeals to me. It is a mathematical problem worked out on scientific principles, just as an engineer calculates the necessary weight of a fly-wheel before it is cast.

2 Mr. Gantt also believes in educating the workman, by setting a mark which must be reached before he can earn the higher rate of pay. Of course the workman doing piece work, depending on his own resources, might become very proficient; though under effective tutorship, the same efficiency will be possible in a much less time. It is an excellent plan to set a higher standard than the average man would set for himself; by proper encouragement and instruction he will usually reach it. The bonus system will bring forth the best efforts of workmen and foremen, and as a result, the maximum product of the plant.

Mr. H. K. Hathaway. Mr. Gantt has brought out most forcibly a feature of the Taylor System that has received but scanty treatment in the various papers heretofore written on the subject. All of us who have served our apprenticeship to the machine trade, can recollect distinctly how little instruction we received, and how most of our knowledge was gained through a process of trial and error. The instruction of the average apprentice is at best a haphazard thing. His foremen, even though they may have the welfare of their apprentices at heart, under the old system of management, are unable to give him anything like the attention necessary to make him an efficient workman in the shortest possible time. Usually the instruction he receives is largely from the workmen with whom he comes in contact and is good or bad, depending upon whether the workman whom

he asks for information is himself a good mechanic, and whether he is inclined to impart the knowledge he possesses.

2 The writer has distinct recollection of setting up a job on a machine when he was an apprentice, in what appeared to him a perfectly proper manner, only to find by its pulling loose under the pressure of the cut when starting, that it was not properly supported. Under the Taylor System, he would have received proper instructions as to just how the work should be set.

3 The writer believes it possible under the Taylor System to turn out a first-class mechanic in about one-half the time taken under the old system of apprenticeship; an opinion borne out by results in a machine shop operated under the Taylor System with which he is connected. In this shop a number of young men, who came to us without previous experience at the machine trade, within a year and a half reached a point where they were capable of turning out work of excellent quality on any of the machines in the shop, and doing it in the time set by the Planning Department.

4 One thing to which the writer hopes Mr. Gantt's paper may lead is the adoption by the trades schools of the methods advocated. Most trades schools pay very little attention, if any, to the time taken by their students for performing the various exercises or tasks forming their course. Too often they have not nearly enough instructors, and boys waste a great deal of time trying to figure out how to do the various jobs; furthermore they have no conception of the feeds and speeds and depth of cuts that should be used in doing work in machine tools.

5 An instruction card prepared for each piece of work, showing the manner in which it should be set in the machine and explaining the various steps of the operation in their proper sequence and the tools to be used, would not only make it easier for the instructor but would enable the student to learn at once the best method, instead of using a method of his own with no foundation in experience.

6 If proper instructions and tools were furnished, and the machine and belts kept in good working order, a definite time could be placed on the job, and the student made to acquire habits of industry. The present methods of instruction may be fine for developing any latent ingenuity of the student, but they certainly waste valuable time. It would be ridiculous to expect a child to write a composition without having first learned the alphabet.

7 Professor Agassiz once gave a student a fish and simply told him to go and study the fish and come back in the course of a week

and tell him what he had found out about it. Naturally enough, when the student came to him, Professor Agassiz told him that his observations were very superficial and sent him to spend another week in studying it. The student did eventually know something of the nature of the fish, but he took about three times as much time as he should have taken to acquire the knowledge.

8 The greatest value of the system of training outlined in Mr. Gantt's paper lies in the fact that in busy times, when skilled workmen are unavailable, it is possible to train inexperienced men, who are intelligent and ambitious, to turn out good work rapidly. The writer has seen an absolutely green man, trained under this system so that in less than a month he was capable of turning out work on a drill-press as satisfactorily as an old hand; of course during this time the "gang-boss," "speed-boss," and "inspector" were almost constantly with him helping and instructing him. After a workman has learned to run a drill-press successfully, he can be trained in about the same time to run a milling machine, lathe or planer.

9 One of the best examples of the efficiency of this system of training workmen, is the results achieved with young college students taken on after their Freshman or Junior year, in the shops with which the writer is connected. After their year in the shop they return to college and complete their course. One object of this plan is to train them in habits of industry, and this object is most successfully accomplished.

10 During this year they are governed by exactly the same regulations as other workmen and are allowed no special privileges of any sort. Under the instruction of the various functional foremen they do effective work from the start. They are started on work of a very simple nature, such as running a sensitive drill-press or cutting-off machine, from which they progress to a radial drill doing a more difficult class of work, thence in turn to the turret lathes, milling machines, planers and engine lathes, spending about two months on each machine; almost from the start these students accomplish the tasks set and earn their bonus, and before the expiration of their time on each machine can turn out as much and as good work as old experienced hands.

11 The progress that can be made with adequate instruction is astonishing even to one familiar with this system, and the writer sincerely hopes before long to see the system applied to the trades schools and the college shops.

12 That the Taylor System is a system whose success is due to

teaching and helping the workman, should be brought out more prominently. In the first place, the proper tools, in first class condition, are provided, and his machine and belts are kept in good repair. Secondly, the gang-boss must show him how to set his work up quickly and in the best way, and not only tell him, but demonstrate it. The inspector must not only detect defects in his work, but must explain, when the workman starts on a job, the drawings, the degree of accuracy, and the kind of finish required. The speed-boss instructs him in the actual operation of his machine, and the setting of his tools, feeds, speeds and depth of cuts, and is prepared to help him if necessary by actual demonstration.

13 Under this system a workman can turn out from two to four times as much work, as his efforts are not largely consumed in finding out what he is to do, devising ways to do it and struggling against discouraging adverse conditions over which he has no control.

Mr. Charles Piez. The bonus system of rewarding labor, which Mr. Gantt describes in his paper, can hardly in itself be considered a system of instruction, and is, in fact, no more an instrument to this end than any of the well known schemes of compensating workmen. It is through the methods Mr. Gantt employs that his work becomes a most effective means for training workmen in habits of industry and coöperation.

2 What appeals to me most in Mr. Gantt's presentation is its distinctly human tone; the spirit of helpfulness toward the worker which it evinces. He recognizes that people as a rule are willing to work at any "reasonable speed and in any reasonable manner if sufficient inducement is offered for so doing, and if they are so trained as to be able to earn the reward," and he finds in the application of his system that "an *instructor*, a *task*, and a *bonus*," prove most useful.

3 Satisfying a man's desire for acquiring skill, or proficiency, setting a task that is reasonable and well within his capacity when properly trained, and paying him a suitable reward beyond his day's pay for accomplishing the task set, constitute a most complete and comprehensive system of training for modern specialized production.

4 Mr. Gantt recognizes the fact that reörganization often means only a change of mental attitude, and that it can, therefore, be best accomplished by persuasion and example. Then, too, while establishing fixed methods of performing tasks, he allows ample opportunity for initiative on the part of the worker; in fact, he stimulates and directs it.

5 In these days when systematizing of industrial establishments has become a recognized specialty in the mechanical world, a few thoughts suggested by Mr. Gantt's paper may not be amiss.

6 There is abroad today a great deal of what might be termed System Idolatry, which manifests itself in the belief that system produces output, when, as a matter of fact, it simply indicates the lines along which maximum output can be attained; and because of this erroneous conception the system assumes the rigidity of a creed, and the various printed forms of which it makes use are invested with a sanctity that is intended to place them beyond the reach of suggestion or criticism whereas they are frequently modified without any departure being made from the underlying principles.

7 The adaptability of an already existing organization, from which the material for carrying out a system must be drawn, the peculiarities of the product, and the demands of the customer must be given full consideration. If the System is considered the important thing, and organization, product and customer must bend to its lines, is it any wonder that attempts at systematizing a plant may fail to result in the full economies promised? And they fail, not because the system is inherently wrong, but because of the fanaticism of the enthusiast applying it. Tact and good judgment must be supplied by the introducer or receiver of the system.

8 I am a firm believer in the efficacy of shop system, for in its essence it implies the production of work along lines of least resistance and greatest economy. But direct lines are not always the lines of least resistance, particularly when they run counter to peculiarities of ability or temperament in an otherwise efficient organization. It seems unnecessary to compel an organization to conform to a system chart, because it is much simpler and more effective to make the chart conform to the abilities of the individuals composing the organization.

9 The first step, even in the mildest form of reörganization, is a partial disruption of the existing organization, and great care and tact must be exercised, lest in the rebuilding, discontent and discord creep in. The line between profit and loss in most establishments is so fine that even a single element of discord can destroy that intangible, profit-making quality, known as team spirit. It is on this account that my interest lies, not so much in this system or that, as in the personality and methods of the men applying it.

Mr. C. N. Lauer Mr. Gantt has adopted a humane, as well as a

scientific, basis for his system of management, and this will do more than any other element towards broadening the field of men working on the problems of management and organization. Mr. Gantt has provided for all the essentials of good management, namely, standardization, task-setting, piece-rating, etc.

2 It has been the writer's experience that the best results, after a definite plan has been laid out, are obtained if the spirit of coöperation can be engendered in the workmen. The manager who depends entirely upon his own ability to drive his employees is bound to fail by just so much as the employee holds in reserve against contingencies which he feels may arise through the whim of the manager. It is the spirit of helpfulness which runs all through Mr. Gantt's paper that especially prompts the writer to pronounce it well worthy of serious consideration.

Mr. Lewis Sanders. I am convinced that the method of shop management described by Mr. Gantt is the logical and correct one for getting the maximum production from our factories at the minimum expense. There is one point that should not be lost sight of, and that is that this system is not a substitute for the proper training of apprentices, and in no way decreases the desirability of it, and I do not think that Mr. Gantt advocates it as such. It is a system that should insure the maximum output from both the skilled and the unskilled.

2 The great advantage of having well-trained men under this system will be that they will continually be improving the manufacturing processes, so as to cut the time of work, and that these improvements will then be applied to the work of the untrained. On the other hand the accurate analysis of the method of doing a piece of work, required by this system, should be added to the course of training of the apprentice. We can then very much increase the speed of special work, where only one or two pieces are made, when put in the hands of men so trained that by practice the elimination of unnecessary operations will become almost instinctive.

3 I have not had the opportunity for direct observation of any plant where these methods have been introduced, but I have seen individual cases where a little study of the methods of doing a piece of work has resulted in marked reduction in time, and this often in classes of work where saving would not be expected; for instance in reducing the time necessary to read thermometers. I recall a test where one of the observers had to read twelve thermometers once

every two minutes. He never succeeded in reading more than eight, and was on the go continually; I took his records and tried to see what could be done; the first few readings I got no more than he had, but by studying just where to stand so as to get the light unobstructed and not to be obliged to shift my position, in a short time I was able to read all the thermometers in 1 min. 50 sec. In another case where three men were required to take the observations, I had to make some laboratory tests with only one available to assist me, and by a little study of the method of taking the readings we soon found that two could take them quite as easily as three.

4 At Schenectady I have seen a 2000-kw. vertical turbine used for experimental work, completely dismantled and a new set of wheels put in, and the machine re-erected and running within 24 hours from the time steam had been shut off. This was done by two machinists and a cranesman. I am informed that the men have now become so expert that they do it in twelve hours.

5 A factory in which I am interested bid on turning out a certain small piece of work in quantity. We made a detail study of every fractional operation involved and made our bid on our estimates, being unusually careful in our figures because the shop had never done any work of the character. Our bid was so low that it was returned to us with a request to revise it, as the customer was sure it was less than the labor and material cost. The customer had already made 80,000 pieces. We had sufficient confidence in our figures to insist on their acceptance as they stood. Our estimated labor and material cost was 36 cents, and at the start they cost us 38 cents, which was cut to 34 cents when everything was being done as laid out. The customer was never convinced that we did not lose money although we made 44 per cent profit. But the customer had never been compelled to analyze every single step in turning out the goods, to find out what the cost should be. They had merely made some and knew what they did cost. We should probably have done the same if we had not been compelled to make the analysis. One of the operations on this job was the setting of the piece in a jig, the man who was put on it taking regularly 1 min. 40 sec. After a study of the exact motions required to pick the piece up and set it accurately we showed the same man how to do it in 20 sec.

6 In speeding up a shop a distinction should be sharply drawn between work done at high speed and work done in a hurry; the first will give perfect goods because the speed is attained by elimination of all the unnecessary motions, the latter bad work because it

is a speeding up of all the operations, necessary and unnecessary. High speed work also involves less labor on the part of the employee, than slow speed work. The man who could read only eight thermometers was going all the time; but there was 10 sec. to rest when reading twelve. The machinist who set the piece in the jig in 20 sec. was doing less work than when he spent 1 min. 40 sec. at it, and the same with the machinists erecting the turbine.

7 This method of handling men is in my opinion susceptible of wider application than machine shop practice. It should give good results wherever the same class of work has to be done repeatedly. The chief engineer of the St. Regis Hotel, Mr. Jurgensen, has had a somewhat similar plan in operation in their power plant for several years, and it has resulted in considerable economy of operation. Those interested in power plant management will find it worth their while to investigate what he has accomplished.

8 There is no question but that it requires a considerable knowledge of men to introduce successfully such a system as Mr. Gantt advocates; the theory might be followed out exactly, and the whole system yet be wrecked by lack of common sense and a little knowledge of human nature. After it has become the routine of a shop, however, that shop should be a very easy one to manage, providing good faith is kept with the men. One obstacle to securing high-speed work is the suspicion of the men that rates will be cut if they show that they are able to earn more than a certain sum per week; and they have been given ample grounds for this. On this account the time determined by expert analysis is the only reliable standard as the men will go as slow as they dare.

9 While quite true that there is a maximum wage that we can afford to pay, it is also true that an agreement with a workman should be lived up to as strictly as a contract with a customer. We have to fulfil our contracts even if we have made an error and find them unprofitable; the same should be done with the workman when we find that we have set too easy a task. Tasks set should therefore hold for a definite period, say a year, unless a change in method is made. Before the task is set it should be the subject of accurate investigation to determine the minimum time possible. If the task set proves too severe it must be corrected at once, as the workman is not a party to the setting of the tasks.

Mr. J. C. Jurgensen. Mr. Gantt's methods are based on a concrete knowledge of the human element, which is sure to result in fair dealing to both men and employers.

2 I feel justified in speaking on this subject, since for more than five years I have used a sort of apprentice system for producing reliable and efficient help for the operation of power plants. Although the conditions in an engine room differ very widely from those in a shop or factory, yet the same principle holds, that men who can make good must be trained. When this is once fully realized, every shop and plant owner will look more favorably at the idea of maintaining a training course for his men, as a part of his routine business.

3 To succeed in the training of men, the leader needs to be well-equipped—he must be able to control himself in the handling of his men, he must be thoroughly familiar with the work and the duties of all his men, and he must be a close student of human nature. He ought to have the instincts of a teacher, he must be a good adviser in many troubles, and above all, he must be just as both judge and jury in settling disputes; he must be sympathetic and yet firm and have determination enough to see that orders are carried out to the letter.

4 The leader must make his men understand that it is one of two things: advance, or make room for a better man; and inducements for compelling a man to see it in that light, such as a nine-hour work-day, reasonable wages, provision for advancement, etc., must be present. It is a question of setting right both the employer's mind and the workman's job, and the Golden Rule must be applied before success is possible. As a general rule, it is necessary to hold out material inducements for acquiring better skill and efficiency. With some, but not with many, ambition and the right temperament will bring this about.

5 To secure safety and economy in an engine room, the men must become willing workers and must take pride in the engineer's department. To reach this point, a man must feel that his position is secure, with a good record, and that advancement and benefit are certain to follow; on the other hand, that a continued bad record will bring discharge. Advancement according to seniority is all right with a qualifying clause—instead of giving preference to the oldest man in the service, make it the *oldest best man*.

6 If opportunity for material advancement is not present when a man has gained his apprenticeship or has reached the highest station possible, we find a new job for him. This is not so hard as it would seem, since other plants are generally willing to take him, and this provides a further chance for advancing the members of the department. Success along this line cannot be had without coöperation,

and this we obtain mainly through a system of rules, and an organized school of instruction in which the Chief Engineer is the Chief Instructor, and each man in charge of a section, an Assistant Instructor in that section of work.

7 In the fire room, the men are paid a good salary for producing one boiler horse power for a certain amount of coal containing a certain per cent of ash: 10 per cent of the value saved over this standard goes to the fireman as a cash bonus each month; on the other hand whatever is lost, according to the standard, is deducted from that man's monthly saving. The head fireman receives a sum equal to half the bonus of each fireman—he is therefore vitally interested in having each man do as well as possible. If a fireman cannot make a bonus, his job is not secure.

8 The coal passers also receive, divided equally between the three shifts, a sum equal to half the bonus of each fireman—they are therefore much interested to see that all the firemen "make good," and yet there is no motive for collusion between the men. It is soon shown that the best policy for both the company and the men is a continued effort to make the bonus as large as possible. All the men in the department are thus taught to follow both daily and monthly standards in work and expenses.

9 To illustrate the scope of our Engineering Department Training School which is a part of the Men's Relief and Educational Society I will mention the objects of the Society, as stated in our by-laws:

Section 1 The objects of this Society shall be the raising of funds to provide a weekly relief income to members in good standing during illness or accident and such other relief as may be deemed advisable, and to assist in defraying burial expenses of a deceased member; also, to defray the expenses incurred in carrying on the training course which constitutes the Educational Branch of this Society.

Section 2 As a further relief, members who are in good standing may apply to the Society for loans, not to exceed 10 days pay of such members' monthly salary. Loan to be paid back in four successive and equal monthly installments, plus 1 cent per dollar per month, on amount due to the Society.

Section 3 The object of the Educational course is to give such practical instruction and example as will further a spirit of manhood and induce the members of the Department to become self-reliant, observing and manly men. Training such men to become safe and conscientious workmen, worthy to receive the Company's Certificate of Merit for two years service.

Section 4 To ambitious holders of the Certificate of Merit, the training course will endeavor to supply the technical information most needed to make such workmen qualify as safe and efficient Operating Steam Engineers, worthy to receive the Company's Operating Steam Engineers' Apprenticeship Certificate for five years service.

Mr. Willis E. Hall. Mr. Gantt's paper dwells upon a component in our industrial situation that must soon have more consideration than it has received in the past. For comparison and analysis, and to avoid confliction, his system should be divided as follows:

a The task basis of compensation, those failing to reach a fixed degree of efficiency receiving only their established day rate.

b The use of an instructor. The duties of the instructor are (1) intelligent determination of the time, on a fair basis of compensation for the work that is to be done; (2) instructing the men to do the work in the way on which the price was computed, which being based on the latest information must therefore be the best method of accomplishing it.

2 Why does the task system of itself promise any better results than those obtained under the piece-work system? The term piece work is here intended in its broadest sense, to include all methods of compensation based on the amount of work done. It therefore includes such modifications designated as the bonus, premium, differential, profit-sharing, gain-sharing, etc. On the contrary the task system seems to eliminate day work only partially. For instance if the employee can not do the work within the time set for the task he receives no additional compensation and his day rate prevails. Assume, then, that the delinquent is replaced by one who can meet the task (and the task system has no monopoly of procedure in this respect, as the same degree of vigilance should be exercised with any system), until the plant has, finally, the very best set of men obtainable; and further that the men are instructed to the highest degree of efficiency (and here again the task method does not possess exclusive privileges). It is unnecessary to substantiate the statement that there will still be a vast difference between the most and the least efficient of the force.

3 How then will you set the task? If it is set so that but a limited number, say 65 per cent can meet it, then the remaining 35 per cent must be eliminated from the rewards. The answer may be that this remaining 35 per cent will have the day rate adjusted according to their relative efficiency. To that extent the task is not better than the day-rate system. The other alternative is to set a task that the least efficient can meet, but neither is this fair to the employer or would it promote efficiency in the employee. In short,

with the task system proposed men must be practically equal in efficiency or it is only a partial eliminator of day work. Unavoidable ruling conditions due to the unequal efficiency of men, instructed or otherwise, seem to prevent this from being other than a partial day-work system for producers. However, this is of minor importance in comparison with the other feature in Mr. Gantt's paper, the use of an instructor.

4 For greater productive efficiency, to the mutual benefit of employer and employee, the use of an instructor, combined with the intelligent piece-work price-setting described by Mr. Taylor (Vol. 14 of Transactions), seems full of promise. That the use of an instructor establishes "habits of industry" of which Mr. Gantt speaks, must not be misconstrued. There is quite a difference, with apology for the terms, between the "sweating process" and "farming the work;" both extremes are equally demoralizing. It is the medium position that is always most difficult to assume at first and the one that is most desirable. It is only by accident it is reached by the haphazard method of establishing piece-work rates at present so generally used, which usually results in one or the other of the two extremes, until the price, after many adjustments, is about where it should have been originally. But by this time some change in the method of doing the work makes necessary a new start. Instruction, establishing industry, does not mean the "killing pace." Ordinarily it is the contrary. Commotion is not necessarily industry; usually they vary in inverse ratio. There is one best way of accomplishing work and that way, when once learned, will be the easiest. Intelligent setting of piece-work rates or task limits with an instructor eliminate the more flagrant abuses of the system. Some existing variables cannot be met with the present status of the mechanical arts, but they are insignificant in comparison with the evils eliminated, and our range of vision should not be limited by a disadvantage of perhaps 5 per cent when there is a 95 per cent gain in sight.

5 Most of us that have been identified with piece work have, no doubt, felt for some time that a modification of the present atrocious abuses of the system was necessary. Mr. Gantt would render an invaluable service to the Society by giving it a comparison of results obtained, with the use of an instructor as the only variable factor. For instance, where the Taylor differential system is in vogue, what additional advantage is obtained by the full use and authority of an instructor? The additional cost should not be overlooked.

6 One other feature, though this is somewhat of a digression

from Mr. Gantt's paper, should be made a part of the duties of the instructing and piece-setting department. It is that of time-checking, where either the piece-work or the task system is in vogue. For instance a producer spends actually $7\frac{1}{2}$ hours on piece-work but has been in the shop some 10 hours in all. There is a loss "for good and all" of $2\frac{1}{2}$ hours of productive time. In other words, what percentage of the producer's time is lost in this way, and why? Is it not safe to say that most of the establishments using piece-work ignore this point? In one instance where the tonnage of a plant was increased more than 90 per cent over what was formerly, at least, normal tonnage, about 30 per cent of this increase was due to the elimination of the annoying and demoralizing delay known as "waiting for work." And yet this delay was previously not over-conspicuous and its magnitude was not appreciated until it was eliminated. There was practically no rate-cutting.

7 Nothing about a shop can be more easily hidden, either intentionally or unintentionally, than this loss of time. The greatest incentive to indulgence in it is a slip-shod method of rate-setting, especially when the known practice of the employer is to await the first opening to slash the price. For this the employer is responsible. His loss is dependent upon the nature of the product and the relative proportion of organization expenses to producer time. The loss to employee is easily computed. That it can be more satisfactorily checked and controlled by intelligence than by the present method of price-setting is self-evident. This, with the elimination of favoritism, should answer the argument so often made, in defense of the present method of setting piece-work prices, that it does not make much difference so long as the "average" rate is about right.

Mr. Harrington Emerson. There has been an almost unanimous chorus of agreement with Mr. Gantt, and music sometimes sounds better if there is now and then a note of discord. I once asked Mr. Gantt what happened in case one of the workmen whose time he had set managed to do the task in less than the time prescribed. Mr. Gantt very cheerfully answered that in that case the workman would take his place and he would have to take the workman's place. Since then my assistants and myself have had to standardize over 100,000 different jobs, and we have never been able to realize the accuracy which Mr. Gantt so flippantly claimed. The reason probably is that Mr. Gantt's work lay along standard lines, working on standard material, in standard manner, while my work lay in repair shops,

working on unstandardized material, unstandardized jobs and unstandardized conditions. In such matters as locomotive repairs we were able to predetermine, within four per cent, both time and cost of the aggregate, but not to strike the exact time of the jobs that entered into repairs.

2 Now Mr. Gantt comes forward with this paper, and we have a chorus of assent to the statement that by training the workmen the problem is solved. My experience has been that this is not at all the end of it. It is easy to train the workman in habits of industry and coöperation, but when you have provided a method for training him, you have not touched the real problem. What I would like from Mr. Gantt is a paper on training managers in habits of logical thought and coöperation.

3 To illustrate the enormous practical and economical importance of this question, I quote the figures on locomotive repairs per mile on four out of the five trunk lines running west from New York. This is not a very accurate standard, but nevertheless it is used. On one of these, 44 mills maintains the power in first-class operating condition; on the second road, the cost is only 7 cents; on the third road 12 cents, and on the fourth road over 16 cents. This fourth road has a mileage of 30,000,000 miles, and the cost is over 12 cents more than on the first road, making the amount of money lost per year $3,600,000. Yet this road has good grades out of New York, while the road that shows the lowest cost has the heaviest grades. (This last statement was in answer to a question from Mr. A. H. Emery.—Editor.)

4 The trouble does not lie with the workmen. No doubt the workmen are wasteful, no doubt they have not been fully trained, but the trouble lies absolutely in the managements which have not yet awakened to their problems, and accept enormous wastes as inevitable.

Mr. Milton P. Higgins. When this marvelous proposition was first advanced two years ago by Mr. Taylor, I looked upon it as a departure of very great promise, and I have not been disappointed in its results. In addition to considerations of shop discipline, efficiency, output, profits, and the well-being of the workmen, as a means of education, I believe it is equally important and efficient.

2 In place of the old system of apprenticeship we have now the training school, the apprentice school, the trade school; but the shop which trains its apprentices to the best advantage to meet modern

requirements has within it a trade school. That is, the task, intelligent analysis of methods, and the bonus, are most effective elements of disciplinary education, not only important as developing skill and efficiency, but developing intellectual capacity and manly character. I believe that the training given in the shop through these methods may be as good as any line of mental and intellectual discipline, that can be offered in a university.

3 In regard to the suggestion Mr. Emerson made, of training managers and superintendents, if we wisely and faithfully train the skilled workmen, are we not training the managers? If we want large trees in the forests, had we not better give our attention to the nursery?

Prof. Wm. Kent. At the meeting in Detroit in 1895, when Mr. Taylor made an address upon a similar subject to this, he met with unanimous dissent from the older men; and I got up in that meeting and said that a man over fifty years of age could not be expected to appreciate Mr. Taylor's paper, and that the revolution in the industry that was to follow from Mr. Taylor's plan was to come from the work of such younger men as Mr. Gantt. I am glad to see that Mr. Gantt has verified my expectations.

2 The hopeful thing about this paper, which I regard as the most important that has ever appeared in the Transactions of the Society, is that it is in harmony with humanitarian ideas. I am glad to see this sentiment throughout the Society. There would be more of it if more of our mechanical engineers would go into shops, instead of into power plants and drafting offices, and offices downtown.

3 The trouble with the managers has been mental inertia. Men of great brain power, enterprising, and in important positions, will not take half an hour, which is worth perhaps $50 to them, to think on a problem which might end in saving them $10,000 a year in the shop. That kind of manager, however, is rapidly being displaced and the younger men, who are willing to do some thinking along the lines of Mr. Gantt's paper, are coming forward to take their places.

Mr. James M. Dodge. I have been asked whether the concern that I am connected with has abandoned the Taylor System, and I desire to be recorded as saying that we have not abandoned it; on the contrary, it is working to our complete satisfaction in Philadelphia and Chicago, and we are introducing it as well in our Indianapolis plant. Mr. Taylor told us five years ago that the introduction of

his system would be of great saving to us in normal times, but that its greatest value would be shown during periods of commercial depression, and I am very glad to be able to say that Mr. Taylor was absolutely correct in his statement. Our business during the past year (1908) would have shown a deficit had we been working under the methods we thought quite excellent prior to our adoption of the Taylor System, which carried us through this twelve months during which our business was curtailed about one-half, with a moderate profit showing on the right side of our annual statement.

(Question by Mr. Frank A. Haughton as to the difficulty in holding together their organization of experts through this period of depression.)

2 I am glad that question was asked, because we did not experience the difficulty suggested. Under the Taylor System the functions of the different members of our organization are so clearly defined, that we were able very promptly to reduce our expenses by demoting a number of our workers, thus avoiding the demoralization of the sub-divisions of our organization. We took the men into our confidence and explained to them the exact situation, and they cheerfully accepted it; in fact we had no trouble at all. Our organization was and is intact, and, as Mr. Taylor told us, can be readily expanded to any desired extent as soon as increased orders make it necessary.

The Author. A system of management may be defined as a means of causing men to coöperate with each other for a common end. If this coöperation is maintained by force, the system is in a state of unstable equilibrium, and will go to pieces if the strong hand is removed. Coöperation in which the bond is mutual interest in the success of work done by intelligent and honest methods produces a state of equilibrium which is stable and needs no outside support.

2 Until within a few years the mechanic was necessarily the source and conserver of industrial knowledge, and on him rested, therefore, the responsibility for training workmen. With the advent of the scientifically educated engineer, capable of substituting a scientific solution of problems for the empirical solution of the mechanic, the responsibility of training workers naturally shifts to his shoulders. If he accepts this responsibility, and bases training on the results of scientific investigation, the efficiency of the workman can be so greatly increased that the manufacturer can afford to give those that take advantage of this training such compensation as will secure their hearty and continuous coöperation, thus making the first permanent advance toward the solution of the labor problem.

3 This was first demonstrated by Mr. Fred W. Taylor, and the whole industrial community has already been profoundly influenced by his work.

4 It was well said yesterday that the work of the engineer has been less appreciated than that of any other learned profession, and a broader recognition of his work will have a marked influence on our civilization.

5 He is carrying forward under the direction of science the work that was begun by the mechanic who first learned to chip flint or make a fire, and it is he alone that can lead the mechanic of today to a better understanding of his problems, and the capitalist to a better appreciation of their solution.

THE PRESENT STATUS OF MILITARY AËRONAUTICS

By Geo. O. Squier, Ph.D., Published in The Journal for December

ABSTRACT OF PAPER

The scope of this paper will best be shown by the following Table of Contents:

Successful Military Dirigible Ballons: France, The Patrie and Ville de Paris; England, Military Dirigible No. 1; Germany, The Gross, the Parseval, and the Zeppelin; United States, Dirigible No. 1. Balloon Plant at Fort Omaha, Nebraska.

Some General Considerations which Govern the Design of a Dirigible Balloon: Buoyancy and Shape; Resistance of the Air to the Motion of a Projectile; Analogy to Airship; Aërodynamic Adjustments.

Representative Aëroplanes of Various Types: The Wright Brothers' Aëroplane; The Herring Aëroplane; The Farman Aëroplane; The Beriot Aëroplane; The "June Bug."

Some General Considerations which Govern the Design of an Aëroplane: Support; Principle of Reefing in Aviation; Determination of k for Arched Surfaces; Resistance and Propulsion; Most Advantageous Speed and Angle of Flight; Stability and Control.

Some General Relations Between Ships in Air and in Water: Helmholtz's Theorem; Skin-Friction; Relative Dynamic and Buoyant Support; Motors; Propellers; Limitations.

Hague Peace Conference; Influence on Military Art; Delimitation of Frontiers; Interior Harbors.

United States Signal Corps Specifications for Heavier-than-Air Flying Machine.

United States Signal Corps Specifications for Dirigible Balloon.

Bibliography.

DISCUSSION

Dr. W. J. Humphreys. The point I am to discuss primarily is the connection of the winds with flying machines. It will be very important for practical navigators of the air to have maps of the winds. Such maps are issued certainly once a day, and may be had

twice a day, or even more frequently, if there be a call for them, as I fancy there will soon be on account of the development of the flying machine. That is evident to every one, but there are one or two points with which perhaps you are not quite so familiar.

2 We find that there is often a great difference in the direction of the winds as we ascend. I have seen the wind change in direction by as much as 30, 45 or even 90 deg., at an elevation of not more than 1000 ft., and in one or two instances I have seen winds differ in direction by as much as 180 deg., at a distance of 1000 ft. above the surface of the earth. It will be necessary to take account of these facts in the navigation of the atmosphere.

3 The winds change greatly in velocity also, at short distances above the surface of the earth. We find by experiment with kites and balloons that near the surface of the earth the air is exceedingly turbulent, after the order of a choppy sea, but at distances of 500 ft. or over, it is more like regular billows, while at an elevation of 1000 ft. the wind is practically steady. Here the aëronaut would neither be in reach of the billows nor run into the ruts and hills and bumps of the invisible air.

4 The direction of the wind can be determined frequently by simply observing the clouds. That will be an aid for the practical navigator, but these changes are different at one place from what they are at another place, and that the practical navigator himself will have to watch. Maps cannot be made for this particular purpose, but what we can get from the map primarily is where the storms are and from what direction the winds will be likely to come for ten or fifteen hours. We have found that around the center of the cyclonic storm, winds will blow in the northern hemisphere counter-clockwise, so knowing the position he is in with reference to the center of the storm, the observer can determine the direction in which the winds will blow. In this section of the country the winds which run at all high in summer always blow practically parallel to the coast line from New York to Boston, while in winter the upper winds are more nearly directed towards the ocean. That may be of importance for the practical navigator to take into consideration.

5 There are many more points of this type that I might bring out, but I believe these are really the salient ones.

Prof. John A. Brashear, who was intimately associated with Professor Langley for three years, in his scientific researches, wished to emphasize the recognition given his work by Major Squier, and thus

to pay a debt of gratitude to a man whom he considered one of the greatest physicists, as well as one of the most generous men of this country.

2 Par. 159, on the most advantageous speed and angle of flight, had recalled to him the very large number of experiments made by Professor Langley to determine these two important points. Professor Langley invented a machine, which he called a dynanometer-chronograph, to record all the experiments which he made, and to his honor be it said that he started into the work not for the purpose of building a flying machine, but of determining the law of flight, and he repeated his experiments time and time again and sent nothing into the world of which he was not practically certain; just as in sending out his experiments on the absorption of the atmosphere as a factor in the possibility of life on the earth, he was just as particular with the data in regard to the former as with reference to the latter.

3 Professor Brashear referred to Professor Langley's failure in attempting the last flight with his aëroplane, and to the unfortunate publication of unjust reports which did so much to check his career and wreck his life. He said: " I want to add one word more, and that is the sad side of it. We have heard of Fulton's being stoned when he started his steamboat and of the anathemas hurled at the men who have been pioneers in the advancement of the world's knowledge. I went into the Smithsonian Institution just after Mr. Langley's unsuccessful flight on the Potomac. Mr. Langley heard my voice in the outer office and came in to me, taking my hand, with bowed head. 'Mr. Brazier,' as he always called me, 'Come in, I want to talk to you.' Picking up two little pieces of steel broken from an original piece and handing it to me he said, 'Here is what has wrecked my life. My life-work is a failure, this broke, and turned my ship into the Potomac instead of up into the air.' And that man could not be aroused from his lethargy and depression. I said to him, 'Professor Langley, your work in the study of the earth's atmosphere and the possibility of life is enough for one man to do;' but it was no consolation to him.

4 "Let us not forget to say a few kindly words, even in the failure of men, and to remember that a great part of this life and of our success in it is made up of our seeming failures."

Mr. Geo. L. Fowler, who was also associated with Professor Langley, gave a few reminiscences of his work, outlining it as follows:

2 Professor Langley started with the idea of determining the resistance and lifting-power of various types of aëroplanes. He

started with the simplest of little instruments, which he projected from the balcony of the Smithsonian Institution down into the larger room beneath. These experiments developed first a motor-driven machine, for which he used the contraction of a rubber band, and then supplemented the work which I believe he had already begun at the Allegheny Observatory, by establishing a whirling table in the lower part of the Smithsonian Institution by which he measured the resistance and lifting-power of the wings of various types of birds and almost every conceivable shape and form of aëroplane, and also obtained the propelling-power of various types of propellers fit for use in the air. On one occasion he built a large propeller mounted on a hand-car which he used on the Pennsylvania Railroad, and obtained possession of a small track on which he drove that car for several days in order to obtain the resistance of the car and also the propelling-power of the machine.

3 I think it was only after the first successful flight of his motor-driven aëroplane that Professor Langley realized the importance of balance. Any one who has seen Orville Wright drive his machine at Fort Myer must recognize after witnessing it for even a few minutes the absolute control which he seems to possess over the machine, and if any here had been present at one of the flights, and had been invited to take a ride with Mr. Wright, they would have gone with perfect confidence. The machine started down a slight incline or monorail, rose, and apparently gave a slight dip—it looked to me as though he had his upper wings elevated to give him the rising power, found himself rising too suddenly, turned back and after a slight hesitation flew away. The steering of the machine was under absolutely perfect control. One thing about the Wright machine I think Professor Langley overlooked in his early experiments. In all early work and in the publications of the Smithsonian Institution, the principle of the bird soaring on motionless wings was repeated again and again. Now an eagle soaring high above the earth appears to be on motionless wings; but, if you will watch a buzzard rising over the land, or stand at the stern of an ocean steamer and watch the gulls following it, you will see that they do identically the same thing as a boy walking on a railroad track or a tight rope walker on the rope with a balancing pole—the soaring bird with his wings out is constantly making sudden, quick motions. That point, which Professor Langley failed to overcome, the Wright Brothers overcame by a slight warp in the upper wing, which has been one of the causes of the success which they have obtained.

4 Professor Langley found on his first experiment that balancing was a great necessity. In his first machine, the weights were carefully calculated in order to determine the exact specific gravity of the whole thing, and then a small hollow tin can four or five inches in diameter and six or seven inches long was placed on the bowsprit to lower the specific gravity to such an extent that the whole machine would float if dropped into the water. When first cast off, the can was pretty well forward, and the machine promptly made a dive head-foremost down into the Potomac. Next the can was moved back four or five inches, throwing the center of gravity back so much further that the machine went up into the air and dropped back tail-foremost into the water. Then the can was again shifted to a point about halfway between the two, and when cast off the third time it swung around in a circle and flew off for a distance of three-quarters of a mile. That was the first successful flight, and the beginning of the application of balance, the self-limiting balance.

5 In his first experiments Professor Langley worked along the lines of least resistance and lowest weight. Everything about the aëroplane was of the lightest possible type; what he wanted was to fly, and the consideration of stress of material would come later; as a matter of fact in calculating his stresses he ran them up almost to the breaking-point of the material, so that there was practically no factor of safety, and perhaps this was one of the causes of his later failure.

6 I remember once a gentleman saying to him, in discussing his boiler, "Well, Professor Langley, that boiler will make steam, but it will be very uneconomical in the use of fuel." "Never mind that, we will burn gold under the boiler, if necessary. What we want is steam," was the reply. The result on the first successful machine was a very great steam producer, but at the same time a very uneconomical boiler in the use of fuel. His engine was of the simplest possible type, a little engine with a cylinder of about 33 mm. diameter, 73 mm. in stroke. Everything about the work was done on the metric system. He succeeded in developing about one horse power. The cylinder of the engine was a small steel tube, about one millimeter thick, and as the steel would not make a good bearing surface for the piston to move backwards and forwards in, he bushed it with a cast iron bushing of the same thickness, which gives some idea of the delicacy of his work. The pump that he used to force circulation in the boiler was of the same small and delicate type. The only thing about the machine really efficient from the standpoint of the steam engineer was his burner. He realized that he must burn his fuel to get as high a

temperature as possible, and spent a great deal of time in developing his burner, which was exceedingly efficient, and with that small machine of about 14 ft. span of wings, he succeeded in making a successful preliminary flight and the machine did repeat this flight on several occasions afterwards.

7 That is a brief outline of what he attempted to do and what he really succeeded in doing, but beyond that, the science of air dynamics has probably been worked in more thoroughly by Prof. Langley than by any other man, and it is doubtful if any one will ever devote so much time and energy to the solution of a scientific problem that promises so little in the way of practical results, as did Professor Langley when he undertook to find out the true theory of flight.

SALT MANUFACTURE

By Geo. B. Willcox, Published in The Journal for Mid-October

ABSTRACT OF PAPER

Some details of construction are explained, that have proved successful in plants for the manufacture of salt by the "grainer" process, including the design of evaporating grainers of reënforced concrete, automatic devices for removing salt from the grainers as fast as it is formed, details of a conveyor for handling salt, and a device for loading salt barrels into box cars.

The purpose of the paper is to draw attention to a few of the features of grainer salt production that may be of general interest to the mechanical engineer in lines other than salt manufacture.

DISCUSSION

Mr. C. F. Hutchings. Before lumber became scarce, the "grainer block" was an adjunct to practically every saw-mill in Michigan. By using their exhaust steam in the evaporation of brine, the fuel cost the mills nothing and the cost of salt-production was confined to pumping the brine and handling the salt, which found a ready market at high prices.

2 Salt-manufacturing establishments increased in number, and brine and rock-salt beds were discovered in many states; the market became glutted and prices fell; and cooperage became so scarce that the barrel cost more than the salt it contained. Manufacturers who were not entirely driven out of the market were compelled to adopt more efficient and cheaper methods of producing salt.

3 Finding themselves in this position about six years ago, my company, after investigation, installed mechanical rakers and conveying apparatus, a class of machinery then new to the market. Our apparatus is essentially that described by Mr. Willcox. After correcting the defects incident to a new departure, we found ourselves in possession of excellent salt-handling machinery.

4 The old-style method had required 10 men to lift by hand and store the product of 8 grainers; by the present mechanical methods, 4 men could handle 10 grainers. In our experience a mechanically

lifted grainer makes no more salt per day than a hand lift, the raker advantage being altogether one of labor-saving.

5 One of the chief requirements in the design of a salt raker is that all parts of the machine that come in contact with the hot brine be entirely submerged in it, as the combined action of brine and air will rapidly destroy the apparatus.

6 The pioneer work of Mr. Willcox in exploiting the reënforced concrete grainer, marks an epoch in the engineering department of

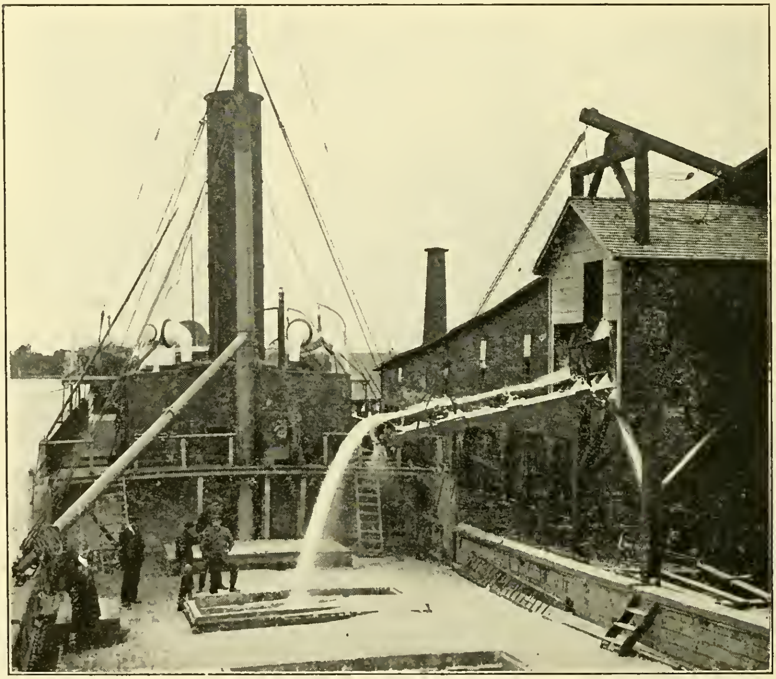


Fig. 1 Loading a Boat with Salt at the North American Chemical Co., Bay City, Mich.

the salt industry. During the construction of these grainers at Saginaw the salt fraternity looked on with distrust, thinking that the variation in brine temperature would soon destroy the work, but the sand joint between grainer and foundation apparently takes care of this point.

7 The scarcity and cost of the high-quality lumber necessary for grainer construction makes the advent of the concrete grainer very welcome. Wooden grainers are hard to maintain and susceptible

to many deteriorating influences. For instance, a wooden grainer can be kept water-tight only by continuous use. It will leak if turned out two or three days for repairs or cleaning; this means the loss of brine and salt for perhaps a week until the leaks are taken up by a fresh deposit of salt.

8 The writer repaired a number of old wooden grainers a few years ago by lining them with 8-oz. duck, saturated with a high-temperature asphaltum compound. The melting-point of this compound is 260 deg., and a grainer seldom shows over 185 deg. The duck, which is $\frac{1}{16}$ in. thick when saturated, was laid with 6-in. laps and all joints covered with the compound and reënforced with strips of saturated duck. After the grainer was well lined another reënforcement of compound was spread over the bottom of the grainer on top of the saturated ducking, and a lining of inch-boards was nailed in the bottom and sides of grainer. This repair job has been running four years and the grainers are still tight, although the original planking is nothing but a bunch of loose fibers which can be pulled to pieces with the bare fingers.

9 As for handling, the belt method is doubtless undesirable with a small but continuous quantity of salt, owing to the liability of the belt-mechanism to collect dirt and spoil the salt. On the other hand, this method is ideal for handling quickly large quantities of salt, a condition exemplified in our salt works at Bay City, where we make salt by vacuum pan as well as by grainer. This salt is carried by belt from the drainage bins which first receive the salt from the vacuum pans to the warehouse bins, a distance of 350 ft., at the rate of 15 tons per hour. The belt is 14-in. operating at a speed of 250 ft. per minute. Five men do the work of handling this 100 tons or 700 bbl. of salt per day; without the belt we employed 9 men.

10 We also have a belt built in a trough across our wareroom floor, with another belt running up an incline at the end to overhang the Saginaw River; under this projecting end a lake-boat of any size can be moored; 30 or 40 men can wheel salt from the warehouse floor in wheelbarrows and dump it into this floor trough, and the salt is forthwith carried by the belt and landed in the hold of the boat. This loading belt is 24 in. wide, runs 300 ft. per minute, and will load at the rate of 150 tons per hour, the rate of loading depending altogether on the number of men at the wheelbarrows. Without this belt we could not load boats with bulk at all, because our warehouse floor is lower than the deck of a vessel.

11 The net result of our installation of salt handling machinery is as follows:

On grainer raking outfit, saved 6 men.

On vacuum pan outfit, saved 5 men.

A total of 11 men saved on handling about 1000 bbl. of salt per day, a cash saving of nearly two cents per bbl. of salt.

The interest charge on these improvements and the repair account come to a very small fraction of a cent per barrel.

The Author. As showing the relative advancement in the development of special salt works machinery in America and abroad, it is of interest to note that the German Government recently sent a commission of salt experts to this country, and as a result that Government has adopted this system and has authorized the building of a large salt works at Schoningen, which is in its essential features of design and equipment practically a duplicate of the plant described in this paper.

METAL CUTTING TOOLS WITHOUT CLEARANCE

By James Hartness, Published in The Journal for December

ABSTRACT OF PAPER

This paper sets forth a turning tool that is intended to cut without clearance.

It consists of a cutter and a holder so constructed as to allow the cutter a slight oscillatory freedom in the holder. The center line on which the cutter oscillates is substantially coincident with the cutting edge. The oscillation of the cutter about the center line does not affect the position of the edge, but it does allow the face of the cutter to swing around to conform to the face of the metal from which the chip is being severed.

The objects of this construction are to make possible the use of more acute cutting edges in order to reduce the cutting stresses; to equalize wholly or partly the unbalanced side pressure on the cutting edge; and to obtain a rubbing contact to prevent lateral quivering.

DISCUSSION

Mr. H. H. Suplee. This paper is entitled *Metal* Cutting Tools Without Clearance, and so my remarks may be a little off the exact subject. A number of years ago I used *wood* cutting tools without clearance in planing machines, for much the same purpose as Mr. Hartness has used his. In the wood planing machine, in order to avoid chattering and get smooth work on high grade hard wood flooring, and work of that kind, the knives were set as truly as possible, and then the cutter head revolved, and a revolving emery wheel was carried back and forth, grinding off the back edge of the knife, to maintain the true cylindrical surface of the revolving cutter head. So a flat edge, or rather a cylindrical edge, was obtained for the back part of the cutting knife. The cutter produced remarkably smooth work. All the knives were doing an equal share of the work, and the chattering and quivering common in many planing machines was almost entirely removed. The real difficulty was that the edges of the tools got so hot after a certain period, that their temper was drawn.

The Author. Mr. Suplee's remarks regarding the use of no-clearance blades in wood-planing machines are full of significance. The question of heat generated by the friction of the riding-contact is one that will require more time to settle definitely. The results may not be the same for different materials. We would expect an important difference between steel and castiron. The extra heat generated in wood-planing may have been due to some or all of the cutters having acquired a negative clearance. The springing of the material or the head would cause substantially a negative clearance. Excellent results are now being obtained by this scheme by the planers made by the S. A. Woods Company of Boston.

2 The whole subject is so full of unsettled points that the author hopes others will be induced to contribute papers, especially along the lines of acute cutting-angles, clearance, and cooling or lubricating solutions.

LIQUID TACHOMETERS

BY AMASA TROWBRIDGE, PUBLISHED IN THE JOURNAL FOR MID-OCTOBER

ABSTRACT OF PAPER

The principle on which the Veeder liquid tachometer acts is that the pressure developed by the centrifugal force of the liquid when the instrument is running at a certain speed is a definite quantity. This pressure forces liquid up the indicating tube and is balanced by the pressure due to the height of the column of liquid in the tube. The indications of the instrument depend entirely on the velocity, and do not change if wear is eliminated. It makes little difference whether the liquid employed be something heavy like mercury, or light, as alcohol. The indications are essentially the same for both liquids.

DISCUSSION

MR. H. H. WAITT. I think the makers of this instrument are to be congratulated on perfecting a device which is very beautiful from a scientific standpoint and which will probably find a large field of application. It offers remarkable possibilities in the way of accurate speed regulation when combined with some sort of electrical or mechanical relay device. With an electrical device one might expect to control the speed within one-tenth of one per cent.

2 The simplest form for such a device would be contacts acting directly on the mercury column. Judging from the experience of past years with arc-lamp circuit regulation, considerable attention would be required to maintain this form of contact in proper condition. Some improvement would probably be made by having a layer of oil on top of the mercury; at any rate it would seem that such a device could be used when accurate regulation was necessary.

3 The difference in head of the indicating column does not provide enough force to operate much regulating mechanism directly. For example, with a 30-in. mercury column, 1 per cent rise in speed would correspond to about 0.6 in. increase in head, which would mean about 0.3 lb. per square inch so that a considerable area in the

shape of a piston, float or diaphragm would have to be used to move anything but a relay mechanism. It is interesting to note that one of the Rateau Turbine patents shows a small centrifugal pump for governing the speed of the turbine through the intermediary of a diaphragm.

4 This instrument could be used as a very simple, accurate and reliable speed-limiting device, by having the mercury or other conducting column on the suction side of the pump; in this could be immersed a contact which maintained a circuit holding a safety-throttle open (in the case of an engine), or in the case of an automobile some part of the ignition circuit could pass through the contact. If the speed rose above a certain amount, the mercury would be drawn away from the contact and the safety device would operate, which would also be the case if the contact were defective or if anything else happened to the circuit. It is conceivable that such a device would not be welcomed with enthusiasm by drivers of fast automobiles.

5 Mr. Trowbridge speaks of the effect of viscosity. I would like to inquire if this effect has been accounted for. At first glance I thought it might be due to the velocity-effect of the impulses due to the individual paddles. These impulses would probably be more marked with the liquids which flow more readily. There would, therefore, be a component of the total pressure which would be proportional to the square root of the mean square of the velocity impulses. The trouble with this hypothesis is that it is not in accord with the facts, and we must look for some other explanation.

6 Possibly it may be on account of the more viscous fluids flowing less readily through the leakage paths so that the static head is not as much reduced by the internal drop due to the resistance.

7 In using the tachometer as an instrument of precision, several points should be borne in mind. In the equation for the indication of the instruments, the force of gravity enters into one member and not into the other. That is, the centrifugal force is proportional to the mass, while the height of the column is dependent on gravity. However, as the maximum range of the force of gravity under ordinary circumstances is only about one-third of one per cent, this would not require a correction in the ordinary uses of the instrument.

8 It is possible that considerable error might come into the observations of pulsating speeds on account of the throttling of the fluctuations at the constricted portion of the column. Unless the approach to the constricted portion and the discharge from this

place be shaped so as to avoid it, we see that we get the dynamic head of the impulse in velocity caused by the pulsations in speed. This then may give us an indication proportional to the squares of the velocity instead of to the first power of the velocity. This exaggeration of the average velocity may not amount to anything in practice, but it might be worth remembering, in case of testing such machines as explosion engines without much fly-wheel effect. The exaggeration of the mean velocity, in a rough way, would be proportional to the square of the variation of the ratio of the minimum to the maximum velocity.

9 It would be interesting to know how much power is absorbed by the tachometers and whether there is much heating of the fluid, and also if the instrument is arranged to compensate for this.

Mr. H. G. Reist. This paper is of special interest to me because I have watched the development of the instrument; and now for a number of years the company with which I am connected have used a large number in testing machinery to determine instantaneous readings of speed, as well as in the laboratory for calibration purposes. Owing to its stability, the liquid tachometer is particularly valuable for the latter purpose. A long tube may be applied to the instrument, enabling the observer to read with extreme accuracy.

2 This form of tachometer is very sensitive; yet it can be read accurately, because the column of liquid is stationary and not subject to the vibration peculiar to the needle of mechanical tachometers. There are no errors due to friction or backlash, as is the case with some mechanical instruments. These errors are frequently not serious, even on mechanical tachometers, but sometimes it is desirable to determine speed accurately and it is very difficult, with mechanical instruments, to make such a measurement closer than about $1\frac{1}{2}$ per cent.

3 The only possible error in using the Veeder tachometer is in estimating the position of the column of liquid in the tube. This, however, can be done with considerable precision. We find in practice that the instruments are fairly permanent, the only variation being a slight change of zero due to evaporation of the alcohol used in the instrument. A variation of $\frac{1}{32}$ in. on either side of the zero-point does not, however, affect the calibration appreciably. It is probable that the substitution of oil for alcohol would reduce even the slight care now required. On account of this evaporation, the Veeder instruments need a little more attention than others, but the precise results obtained more than make up for the extra care.

Prof. W. F. Durand. In connection with the statement of the theory of this instrument, attention may be called to the formula for centrifugal force. The use of the formula seems to imply that the pressure head developed by centrifugal pump is $v^2 \div gr$, or in other words that the pressure developed at the periphery of the rotating water is measured by the centrifugal force due to a mass W, rotating with velocity v at radius r, or by $Wv^2 \div gr$, the common formula for centrifugal force. It is well known, however, that the pressure-head developed by a rotating cylindrical body of water is due to an integration of elementary centrifugal force effects distributed throughout the entire body of water, and that the result of this summation at the periphery is to give a pressure head measured by $f\ (v^2 \div 2g)$, where f is a factor drawn from experience. This difference has no practical influence on the relation of the indication of the instrument to the speeds of rotation, since in any given instrument the radius is constant, and the pressure-heads will vary as the square roots of the rotative speeds.

2 The main point indicated is that the pressure-head depends primarily on the linear peripheral velocity, and except for secondary influences is independent of the radius except in so far as the latter is a factor of the linear velocity.

3 Some twenty years ago, I began introductory experiments on certain forms of fluid tachometers, which were interrupted by a change of location and have not been taken up again. One indication of these experiments was the dependence of the readings of such instruments on the physical characteristics of the fluid, especially as regards viscosity, a point which has been examined in the Veeder instrument, with promise of further study.

4 One point comes out very clearly in the study of such instruments, that in order to be reasonably independent of fluctuating conditions the indication of the instrument should be made by the same liquid as that employed for producing the primary pressure-head. In this manner, as pointed out by the author, the density-factor may be eliminated and the indication made practically independent of this factor. There seems to be, however, one possibility of slight error due to the imperfect elimination of this factor. After the instrument has been at work for some time, the liquid within the case will have become somewhat elevated in temperature, with corresponding decrease of density. There is, I believe, no replacement of the liquid in the column, hence there may arise in this manner a permanent difference of temperature between the liquid within

the pump and that in the column. Unless this difference remains sensibly constant, and unless the calibration of the instrument includes the influence of such difference, such temperature effect might introduce slight error. It would be interesting to learn if indications of any such error have been observed.

THE AUTHOR. In regard to the use of a tachometer for regulating the speed of a machine, I agree with Mr. Waitt that the tachometer should be used only as an automatic switch or controller. The use of a film of oil on the mercury column was tried in the testing-machine described but it was discarded in favor of a condenser. When the condenser is used, very little trouble is encountered from the spark caused by the breaking of the circuit; when a film of oil is used on top of the mercury column, this leaves a thin skin of oil over the point which makes contact with the mercury, and the current must break through this insulation before making contact.

2 The reason for the more viscous liquids giving a higher column than the less viscous is probably found in the smaller flow through the leakage-paths. This is one of the points that we have still to investigate.

3 As pointed out by Mr. Waitt, a slight error in the indications of a liquid tachometer is possibly due to irregularities in the speed. The instrument may indicate slightly high because the mean sum of the squares of the velocities of the paddle is greater than the square of the mean velocity. These errors are fortunately very small, and it is seldom required to indicate the speed of an irregularly driven shaft very closely.

4 The power required to drive one of these tachometers is extremely slight, so small, in fact, that we have not yet measured it. Some notion of the ease with which they are driven can be obtained from the fact that one of the automobile-type instruments was driven for more than 46,000 miles on the Boston Elevated Railroad by a wire-wound flexible shaft of $\frac{1}{8}$ in. diameter. This shaft had to make some turns and hence would have given out long before completing this run had much work been required of it. It has not yet broken.

5 The loss of liquid from evaporation, noted by Mr. Reist, amounts to almost nothing, and the variation in the amount of liquid which is permitted in the instrument by the use of the displacement plunger is sufficient so that no liquid needs to be added for a long while. The substitution of oil for alcohol makes the action of the instrument

slightly slower, so that the alcohol has been considered the most satisfactory liquid. Kerosene oil, in which is used in the automobile instrument, adheres somewhat to the glass and makes the indications slightly less clear than when alcohol is used. It is also objectionable on account of its penetrating quality.

6 Referring to Prof. Durand's remarks on the pressure-head developed by centrifugal pump; while there is a factor introduced by the integrating of the elementary centrifugal forces, this, as he points out, has no practical effect in these instruments. In an instrument where the paddle has short blades in proportion to the radius of the hub, more care has been found necessary to keep the instruments accurate. A fair length of blade must be used or the inaccuracies of the instrument have some effect on the indications.

7 The point raised by Prof. Durand in regard to the change in the density of the liquid has not so far proved to be very important. The liquid does heat very slightly in the paddle-case, but it can be thoroughly mixed with the cooler liquid in the column by stopping the instrument for a few seconds, allowing the column of liquid to drop. In certain experiments to determine the effect of the rise of temperature it was found that by considerable heating of the pump without heating the liquid column some change could be made in the indications of the instrument. This change was not serious unless the range of temperature was very much greater than has ever been encountered by the heating of the instrument from its own work. The instrument heats very little when alcohol is used; and even with a heavier liquid, like mercury, no serious difficulty has been encountered from this cause. Rise in temperature due to using it in a warmer room than that in which it was calibrated, has no sensible effect on the indications, as the density of the liquid is practically uniform throughout the instrument in this case.

8 In setting up any of these instruments, they should be so arranged that they can be stopped occasionally, allowing the liquid to come to rest. It can then be readily observed whether the setting to the zero mark is correct, and the liquid from the column can become mixed with that in the instrument, thus obviating any trouble from change in density.

INDUSTRIAL PHOTOGRAPHY

By S. Ashton Hand, Published in The Journal for November

ABSTRACT OF PAPER

Industrial photography calls for results of the highest order.

The lens used should be of long focus; never shorter than the diagonal of the sensitive plate.

Machinery to be photographed should be painted a "flat" drab color. Parts in shadow should be painted a lighter shade than more prominent parts.

Light should come from one direction only, and at a downward angle of about 20 deg. from the horizontal.

In focusing, the points of sharpest focus should be midway between the center and the edges of the ground glass.

No matter how much the camera is pointed up or down, the ground glass should always be vertical.

Exposure should be ample. An under-exposed plate can never show what the light has never recorded upon it.

DISCUSSION

Dr. C. J. H. Woodbury. I am a photographer by proxy only, but will give my experiences with bright metal work, in having photographs made of machinery.

2 Many years ago, the late John C. Hoadley, a member of this Society, extensively advertised the portable steam engines made by him at Lawrence, Mass., by means of photographs for which the finished metal work was whitewashed, giving excellent results.

3 In photographing silver, shaking a bag of cheese cloth containing face powder near the articles, until the white dust has settled upon the object and cut off the glare, has given more satisfactory detail than the putty process, as putty contains yellow tints not visible to eye, but giving in a photograph noticeably darker effects than those of silver. Where silverware is extensively photographed, the articles are arranged, and the camera focused; then they are removed to a refrigerator, and chilled; on being replaced in position the moisture

from the air condenses upon the cold surfaces, and the photograph is taken before it accumulates into drops.

4 Photographers claim to obtain the best results with small diaphragms, moderate lights and long exposures. Interiors containing much detail can be photographed by darkening the room, drawing the curtains, closing the blinds, and giving an exposure of from one to two hours, with a small diaphragm, after which the camera is closed, and the blinds are opened and the curtains raised to admit the light, and a snapshot is taken, using a larger diaphragm; the result will be a photograph revealing detail to an extent not possible with single exposure.

5 A public building decorated for a civic celebration with flags, bunting and many incandescent lights was successfully photographed by first taking an insufficient exposure during the day, and then without moving the camera taking another exposure during the electric illumination in the evening, with the result that the building was faintly shown in the photograph much as it appeared to the observer in the evening.

Mr. Henry B. Binsse. I would like to take issue with the author about one point—he says that the machinery should be painted a drab color. Of course I have not had as much experience as he, but the best results which I have ever obtained have been from painting the machines a salmon pink. The effect of drab color was to make a machine look flat, while if painted a warm color the parts stand out more; you get more of a picture.

Mr. Charles W. Hunt. In connection with Mr. Hand's paper it may be of interest to submit a record of some experiments made by the writer for the purpose of estimating the proper time of exposure for dry plate photography. The following tables are based on this series of experiments. As a preliminary step the altitude of the sun was calculated, for each hour of the day from sunrise to sunset, on the first day of each month in the year, and the results plotted.

2 In June 1905 a series of exposures was made with a Watkins exposure meter at each hour of the day, and a tentative table of the relative exposure time for each hour from sunrise to sunset was made. Using this tentative table a series of similar exposures was made with dry plates. The plates were each developed the same length of time and in the same strength of developer. From these tests the tabular time was corrected.

3 A table was then made giving the estimated time of exposure for each hour of the first day in each month in the year, basing the time of exposure largely upon the tests and the altitude of the sun in the different months. During the ensuing year this table was tested from month to month, and revised as experience indicated, in order to get the best attainable negative at any hour of the day in any month of the year. The present table is derived from the results of the above tests, with the formulae corrected to correspond with exposures made on Eastman films of the current year (1908).

4 The time for a theoretically perfect exposure, that will result in the best printing negative that the subject will give, cannot be expected from any formula that takes into consideration only the most prominent factors affecting the problem. These rules may, however, be expected to give a reasonably close approximation to a perfect exposure.

5 In making exposures, where it is unusually important to secure a good negative, and the exposure cannot be repeated, proceed as follows: Compute the proper exposure by the formula. Then give three exposures: (1) The first exposure with time as computed; (2) The second with one-half the computed time; (3) The third with double the computed time.

6 For less important cases, but where great uncertainty exists as to the proper time of exposure, proceed as above, but make only two exposures, the slowest and the fastest, omitting the computed time exposure. The latitude of the plate will give a satisfactory negative if the theoretically perfect time of exposure lies within very wide limits.

7 An exposure should not be made in a fog, and in hazy weather only of nearby subjects. Good negatives may be made during a shower if the weather is otherwise clear. Generally, if contrast in the negative is desired, "underexpose;" if definition in the shadows is wanted, "overexpose." When in doubt, it is safer to "overexpose." Stops number 64 or 128 are excellent for general outdoor exposure; number 32 or 16 for indoor work. If it is desirable to emphasize a specific part of a machine focus carefully with a large stop and shorten the exposure to correspond with the stop.

8 The following formulae and tables are based on normal light conditions and ordinary subjects. If either or both are abnormal, the operator must make an allowance in the duration of exposure as computed by coefficients from Tables 1, 2 and 3.

TABLE 1 COEFFICIENTS (A) FOR PHOTOGRAPHIC EXPOSURES IN THE LATITUDE OF NEW YORK

Month	Hour of the Day				
	7 to 8 or 5 to 6	8 to 9 or 4 to 5	9 to 10 or 3 to 4	10 to 11 or 2 to 3	11 a.m. 12 m. 1 p.m.
January—December	..	2	4	6	7
February—November	..	4	5	7	8
March—October	2	5	6	8	12
April—September	4	6	9	12	16
May—August	5	8	12	18	28
June—July	7	10	16	24	32

TABLE 2 WEATHER COEFFICIENTS (B)

Clear, sunshiny weather	1.
Floating, white fleecy clouds	1.
Overcast, but a light day	1.5
Cloudy, dull day	2.
Lowery, heavy clouds	4.

TABLE 3 SUBJECTS: COEFFICIENT (T)

Shop interior, dark and poorly lighted	1000.
" machinery fairly well lighted	400.
" machinery placed near a good window light	150.
Machinery under sheds with one side open, or covered areas	15.
" outdoors to give details in the shadows	2.
" " general views	1.5
Groups, or portraits outdoors	1.
Buildings and nearby landscape	1.
Distant structures or landscape views	0.5

TIME EXPOSURE

9 Assume a stop suitable for the subject and call it H; then the seconds to expose will be:

$$\frac{H \times B \times T}{32 \times A} = \text{seconds exposure for an } H \text{ stop} \qquad (1)$$

BULB EXPOSURE

10 A "quick" bulb exposure is a time exposure of about $\frac{1}{5}$ to $\frac{1}{4}$ sec. To compute the number of the lens stop use the formula:

$$\frac{8 \times A}{B \times T} = \text{stop for a "quick" bulb exposure} \qquad (2)$$

Mr. H. H. Suplee. I have used with a good deal of success flashlight powder in connection with daylight, to emphasize the dark part of a machine, where it is impossible to get proper light on small

parts; a small flashlight discharged out of the field so as to reflect the light on the machine will supplement time-exposure and bring out the parts which would not otherwise be visible.

2 My own experience is that it is almost impossible to compute the time of exposure with any accuracy when there are so many variables. The amount of light has to be estimated always, and in my opinion the best plan is to use a moderately slow plate and give a long exposure. If the plate is developed with a long development, you will get detail which you could hardly calculate or compute by attempting to work at any definite time of exposure.

3 Photography has been put to very important uses in engineering work lately, in connection with moving picture machines. We saw last night moving pictures showing the operation of a modern flying machine. They have also been used to show the operations in the workshop, by mounting the machine on a car, and running the car at moderate speed, and the picture machine at full speed, through the shop, the result being a lesson on shop practice, which can be used in a course of lectures more effectively than any other possible means.

4 Several years ago I suggested the possibilities of the moving-picture machine as a means of engineering investigation. It is possible to run the machine very rapidly and get a succession of pictures that represent a very short duration in making the strip. This film can then be run through the picture machine at a speed much slower, with the result that an operation so quick as to be imperceptible to the eye is slowed down so as to be readily examined. I have made no experiments, but I think it is possible, for instance, to photograph a fracture of a piece in the testing machine, occupying only a few seconds at the critical moment, so rapidly in an artificial light on a continuous film, that it could later on be thrown on the screen and slowed down so that the whole sequence of rupture would be plainly visible. Many other applications will suggest themselves for studying phenomena altogether too rapid to be examined by the eye. I believe these matters are likely to be applied to the laboratory, and possibly to workshop operation.

5 Another use is that of keeping a record of the progress of work, a record which cannot be disputed; this is often applied by contractors and builders day by day, to keep a record of the operation of buildings, etc.

6 Another use of photography, which I employed a number of years ago with a good deal of success, is for preserving a record of valuable drawings in a limited space. A full set of complete double

elephant drawings of a whole line of machines were photographed down to $6\frac{1}{2}$ by $8\frac{1}{2}$ in., and a set of prints were made, which formed a parcel that could readily be put away in a safe deposit drawer. In the case of the destruction of the originals by fire, these could be enlarged back to the original dimensions, and thus a perfect fire insurance is obtained for a valuable set of drawings.

Dr. Woodbury. As an example of the use of photography to represent the operation of machinery, the makers of a magazine loom which contained many new and important features had a series of moving pictures taken showing one of these looms in operation, and half-tone plates were engraved from these continuous negatives.

2 These half-tones were printed on a series of small cards hinged together and placed in a small portable device resembling a stereoscope so that by turning a crank the pictures were revealed in rapid sequence, and one could see the loom operating at normal speed, or by turning the crank very slowly, the various operations of the mechanism could be noted in a way not possible of observation when the machine was in its normally rapid operation. Many of these sets of illustrating devices, which were merely those used for a long time in moving-picture shows, were placed in the hands of salesmen and were doubtless the cause of the rapid introduction of this loom.

3 At the other extreme, photography has been used to analyze very slow motions, as for example, a growing plant, which was photographed day after day, the results when put in a moving-picture machine giving the method of extension of the plant. About twenty years ago, the late Col. W. E. Barrows, a member of this Society, built a mill at Willimantic which contained a great many novel and original features, and weekly photographs were taken and sent to members of the board of directors to illustrate the progress of the work.

4 When one of the recent half-encyclopedias and half-dictionaries was in process of preparation, a great many of the more valuable manuscripts were photographed down to about the size of a postage stamp for a page, and the negatives of the photographs were kept in a safe-deposit vault. These instances merely indicate that the dry-plate method of photography has placed in the hands of laymen without the expensive plant and skill of the old-time photographer, the ability to show things, as the author stated, as "they are" and

to give a true record of the progress of work or the existence of any forms of machines or other objects.

Mr. Ambrose Swasey complimented Mr. Hand on his photographs of machinery and interiors and pronounced the paper of very great value to the Society.

The Author. The use of face powder as well as of refrigeration, in photographing articles of silver, are both new to me, but I think either would be excellent for the purpose.

2 Whether small diaphragms, moderate lights and long exposures produce the best results, will depend on the amount of contrast in the subject to be photographed. Size of diaphragm and length of exposure must be governed entirely by conditions and no set rule can be given governing their relation to each other.

3 The methods of making photographs of illuminated buildings and of interiors, have been successfully practiced for years.

4 Painting machinery a salmon pink would be all right for photographing in a very subdued light. I have never had any trouble in getting plenty of contrast with machinery painted a drab color. In fact, I have to give long exposures to avoid too much contrast.

5 Mr. Hunt has gone into the matter of exposures very thoroughly, but he has left out of his table of weather-coefficients one very important condition of light, and that is its color. A day may be clear and sunshiny, but if the light is yellow an exposure of four to ten times that deduced from his formula may be necessary. Exposure-tables are all right for the first guess, but any one of the many factors to be taken into consideration may so upset all other calculations that experienced photographers have never used them to any extent.

6 The use of flash-powder in connection with daylight exposures to emphasize dark parts of machines, is all right, providing there are no projecting parts to cast shadows. Shadows cast by flash-light are very intense.

7 For the successful use of a moving-picture machine in the shop, the shop must be a very well-lighted one, or a lens with an enormously large opening in proportion to its focal length must be used.

8 I have been asked if I have had any experience in showing by photography whether buildings were plumb or not. An interesting experience that I had several years ago will serve as an answer.

9 While the Bourse Building in Philadelphia was in course of construction, a man asked me to photograph the steel structure which had just been erected. I found he was one of the kind of men who write for the daily press on all sorts of civic question, signing himself "Pro Bono Publico," or something of like nature. By great difficulty we obtained a position on top of a building where we could get a good view of the steel work. After getting my position and focusing the camera, I asked what he wanted the photograph to show. He said the steel work was out of plumb and he wanted the photograph to show it. I turned to him and said, "Which way do you want it out of plumb? I will make it either way you want it."

POSSIBILITIES OF THE GASOLENE TURBINE

By Prof. Frank C. Wagner, Published in The Journal for Mid-October

ABSTRACT OF PAPER

In order to reduce the temperature of the gases at the turbine wheel, either an excess of air or water injection may be used. The relative efficiencies of the two methods is shown to depend upon the amount of compression used, and the efficiencies of the turbine and the air compressor. The work required to compress the air may be materially reduced by using two-stage or three-stage compressors with intercoolers. It appears that with high compression the gasolene turbine may be expected to give efficiencies comparing favorably with the reciprocating gasolene engine.

DISCUSSION

Dr. Sanford A. Moss. Theoretical computations such as those of the present paper are very fascinating and the ground has been threshed over many times. The case which Professor Wagner considers is customarily called the "Brayton" cycle.

2 The cycle originally proposed by Diesel had addition of heat at constant temperature, not at constant pressure. The Brayton cycle, with cooling by excess of air or by water injection, is considered in most of the references given below. Theoretically, this cycle is not the most perfect one and much better results are computed by some of the authors with addition of a regenerator.

3 Complete computations of the whole subject, with cooling by air excess only, and without allowing for losses of any kind, were given by Dr. Harvey N. Davis, in an article entitled P Q Plane for Thermodynamic Cyclic Analysis, Proceedings of The American Academy of Arts and Sciences, vol. 40, no. 19, April 1905. Other computations similar to those made by Professor Wagner have been given in many papers of which the following may be mentioned: Scientific Investigation into the Possibilities of the Gas Turbine, by R. N. Nielson, Proceedings of the Institute of Mechanical Engineers (London), October 1904, p. 1061; The Gas Turbine, by Alfred Barbezat, Schweizerische Bauzeitung, about 1904, copied extensively

in the Continental press; The Gas Turbine, by M. L. Sekutoweitz, Memoirs of the Society of Civil Engineers of France, February 1906.

4 An exact analysis of the subject is manifestly impossible, owing to our absolute ignorance of the specific heats, densities, amounts of dissociation, nature of expansion, corrections to perfect gas laws, etc. Therefore, various assumptions have to be made, and the validity of the efficiencies and temperatures computed is very uncertain; and no conclusions should be drawn regarding the differences with one set of initial conditions and another. The temperatures in particular are open to serious question and it is highly doubtful if the computed weights of water, air, fuel, etc., would give the computed temperatures of the paper.

5 As I understand the computations, Professor Wagner handles the expansion of a mixture of superheated steam and products of combustion in the following way:

6 He assumes a final temperature of 1200 deg. and computes a maximum temperature of 2225 deg. for expansion between the given pressures, under the assumption that the mixture of steam and products of combustion acts as a perfect gas with a specific heat ratio of 1.39.

7 He then computes the respective quantities of products of combustion and steam by assuming 0.25 as specific heat of the products of combustion and 0.47 as the mean specific heat of the superheated steam, the latter figure being on the basis of Professor Thomas's experiments. The temperature of the steam at the end of the expansion is then computed by assuming it to be a perfect gas with a ratio of specific heats of 1.31. This comes out 1340 deg., a number different from the originally assumed figure of 1200 deg.

8 The work done by the products of combustion is found from the initial and final temperatures of 2225 and 1200 by assuming a perfect gas with specific heat of 0.25. The work done by the superheated steam is found from the initial and final temperatures of 2225 and 1340 by assuming a perfect gas with specific heat of 0.47.

9 Probably the assumptions made are as good as any other set of assumptions in the light of present knowledge. It is also possible to handle the computations in other quite different ways. The adiabatic expansion of a mixture of two perfect gases is the same as the expansion of a perfect gas having specific heats which are between the actual specific heats in ratio of the respective proportions. In view of the assumptions, it does not seem proper to draw any definite conclusions from the numerical results given in the paper.

PROF. CHARLES E. LUCKE. One of the primary elements in any gas turbine is the nozzle which transforms the heat into work. Understanding this, I made an investigation of some nozzles some time ago and ever since have been investigating nozzles more or less diligently.

2 The value of a nozzle as a heat transformer, when handling a perfect gas, is directly measured by the extent to which it can cool the gas in giving it velocity. So there is no better measure and none more easily applied, than the difference in temperature between the gases entering the nozzle and the gases at the point of maximum velocity. Unless nozzles can be shown to have the power of very materially cooling gases of a given pressure drop by velocity imparted, a successful turbine can never be built. I have never succeeded in making the temperature drop exceed 18 per cent, judging by the methods of determination available, of what would have been accomplished by using a cylinder. In view of that fact it seemed to me not worth while to spend time clothing the rest of the mechanism in metal.

3 I urge those interested in this problem to consider it from the viewpoint of simple experiment. Do not lay out a lot of compressors and turbine wheels and design the details of the bearings; do not make a lot of patent drawings, but go into a laboratory, which may be only your cellar, and make actual compressed air experiments: anybody can produce enough with the water pressure in the house; and when a nozzle has been formed that, working with a moderate pressure, say 30 lb., will freeze water on itself, then it will be time to talk about gas turbines as engineering possibilities removed from speculation.

4 It is quite likely that with a mixed gas turbine, involving the addition to the fixed gases of some steam formed by the internal combustion, different conclusions will be in order. Concerning this sort of possibility there are no data on record beyond some figures for complete machines, which it is impossible to analyze. The laws of expansion for mixed steam and gases can be derived for various ratios of weights and measures found for the effectiveness of the heat transformation into work. The perfection of any nozzle will be determinable by comparing the measurements of effects made by means of it with those that might be computed by the thermodynamic laws. Whenever this comparison shows the nozzle to be as good or nearly as good a transformer as a cylinder, then it will be time to consider a form of mechanism to carry out the turbine

action completely, that is to say, design the turbine; but as I see the question this problem should not be approached before data of the above sort are available.

Prof. Wm. Kent. I have given a great deal of study to this subject and, in my book on Steam Boiler Economy, in the chapter on Combustion, I have given an argument in favor of the higher heating value of 62,000 B.t.u. for hydrogen in all calculations connected with fuel. The argument from the lower heating-value is that we cannot utilize all of the heating-value in any process in which the gases escape into the atmosphere at a point higher than 212 deg., as in most producers and gas-generators. But if we are going to subtract from the higher heating-value, or 62,000, a certain number of heat-units, and say the heating-value is 57,000 because we cannot recover the latent heat of the water-vapor, why not go further and say we cannot recover all the heat of nitrogen of the air used in burning hydrogen and the heat in the excess air, due to its escape at a high temperature?

2 I have shown in that chapter several different lower heating values of hydrogen, depending on the composition of the gases of combustion and on the temperature at which the gases are supposed to escape. If we start with hydrogen at 62,000 B.t.u., and call that 100 per cent, then in making a heat balance a certain percentage is transformed into work, say 20 per cent, a certain percentage is lost in the sensible heat of the gases escaping in the chimney, say 30 per cent, perhaps 10 per cent is lost in latent heat of the water-vapor escaping, and the balance is lost in the cooling-water and in radiation.

3 Why should we not charge all these losses against the 62,000 making the efficiency 20 per cent, instead of first deducting the assumed heat lost in the latent heat of the water-vapor, 10 per cent, and reporting the efficiency as $20 \div (100-10) = 22.2$ per cent? As most of the existing literature on combustion deals with the higher heating-value, why should we bring confusion into the subject by using the lower value?

4 In regard to Professor Hollis' curve showing the relation between hydrogen and total volatile matter; in that same book of mine there is a curve showing the relation of the heating-value of the combustible portion of coal to the percentage of volatile matter in that combustible. In this curve it will be seen that the heating value of coal is the highest (15,750 B.t.u. per pound) when the volatile matter is 20 per

cent of the combustible corresponding to Pocahontas or other semi-bituminous coals. In anthracite the combustible part has a heating-value a little higher than that of carbon, say 14,900.

5 Now, studying the results of Mahler's work in France, I plotted his figures around this curve, and found the whole field of his work covered a very narrow field, in the coals having less than 36 per cent of volatile matter in the combustible, all the observations plotting near to the curve, but beyond 36 per cent the field broadened so that some coals high in volatile matter might have a heating-value considerably higher or lower than that indicated by the curve. In other words, the relation between the heating value of the coal and the volatile matter up to nearly 40 per cent may be expressed by a curve, with an error of not over 1½ per cent as a maximum; beyond 40 per cent, however, coals of different districts may have a very wide difference in heating-value, although their percentage of volatile matter as shown in the analyses may be the same. The difference is due to the different percentages of oxygen in the volatile matter in these several coals, the higher the oxygen the lower being the heating value.

THE AUTHOR. Referring to the remarks of Dr. Moss, I compared the cycle of the turbine considered with the Diesel engine, not because Diesel was the first to use such a cycle, but because the Diesel engine is the best-known example at the present time.

2 It was not my purpose to present a complete discussion of the gas-turbine, but, as stated in the opening paragraphs, to show how the several methods of reducing the temperature of the gases were affected by variations in the efficiencies of the turbine and the compressor.

3 The statement given by Dr. Moss of my method of calculating the expansion of a mixture of superheated steam and products of combustion is substantially correct. The mixture would be at some temperature between 1200 and 1340 deg.

4 The change in the value of the efficiency produced by using a somewhat larger proportion of water, so as to bring the final temperature of the mixture to exactly 1200 deg., amounts to about one-half of one per cent. It hardly seems worth while to attempt such refinements in the calculation.

5 It may be true that more accurate determinations of the specific heats at high temperatures will change the particular values obtained for the several efficiencies. I hardly think, however, that the

relative efficiencies of the different methods of cooling will suffer material changes thereby.

6 The practical value of the calculations I have presented lies in showing what conditions of operation should be avoided. It appears that with low compression and inefficient turbine or compressor, a zero efficiency is to be expected. Some experimenters seem to have obtained this result.

7 Professor Lucke states that he has never succeeded in making a perfect gas cool itself materially in free expansion. I should be very much surprised if he had succeeded. So long as no energy is taken away from the gas, how can it be cooled? In free expansion of a perfect gas, the external work done upon the gas as it issues from the higher pressure is exactly equal to the external work which the gas must do in making room for itself at the lower pressure.

8 In the Engineering Magazine for August 1906, Professor Lucke describes the experiments which I suppose he has in mind when he speaks of 18 per cent as the maximum ratio of the temperature drop, as compared with expansion in a cylinder, that he was able to obtain. In these experiments the air was used to drive a Laval turbine-wheel, and its temperature was measured after it had substantially come to rest in the exhaust. The proper interpretation of the experiments is that an amount of energy corresponding to the observed drop in temperature was abstracted by the turbine-wheel. The tests show nothing at all regarding the temperature of the air as it left the nozzle or as it passed through the wheel.

9 The expansion of the gases in the nozzle of a turbine is not a case of free expansion. The gases attain a very high velocity at the expense of the heat-energy, and are correspondingly cooled. If the energy due to this velocity is delivered over to the turbine-wheel as mechanical work, then the gases will remain cool. Whatever energy is not converted into mechanical form in the wheel is transformed back into heat when the gases are brought to rest.

10 It is not to be expected that the full lowering of temperature corresponding to adiabatic expansion will be obtained practically in a nozzle. The friction work in the nozzle will be converted into heat, and tend to raise the temperature of the gases. So also will the friction work at the vanes. But these effects ought not to be greater than in the corresponding parts of the steam turbine.

A METHOD OF OBTAINING RATIOS OF SPECIFIC HEAT OF VAPORS

By A. R. Dodge, Published in The Journal for Mid-October

ABSTRACT OF PAPER

A method of obtaining ratios of specific heats is given which does not involve the use of available steam tables conceded to be too inaccurate for such investigations, nor a condition in which the steam is presumed to be without moisture or superheat.

This method is based upon the expansion of initially superheated fluid in a throttling calorimeter, and tables are included showing data for steam.

DISCUSSION

Dr. Harvey N. Davis, who had been particularly interested in Mr. Dodge's work because of its possible bearing on his own paper, following it on the program, expressed his gratitude to Mr. Dodge and to the General Electric Company for the opportunity freely afforded him of examining the apparatus used and of studying carefully for some weeks the original records of the observations. He further said:

2 "Mr. Dodge's scheme of keeping the two pressures constant during a run, together with the extremely ingenious graphical method which he has devised for the interpretation of his results, are a notable advance in the technique of throttling calorimetry. Indeed they are among the most original contributions in that field since Professor Peabody's invention of the instrument. I believe that the throttling calorimeter will turn out to be the most sensitive and valuable instrument at our disposal for the investigation of the thermal properties of superheated steam and other vapors. Any future experiments with it ought certainly to be so arranged as to be immediately available for discussion along the lines laid down in this paper. It would, of course, be an advantage, could the arrangement be such as to facilitate also such a discussion as is suggested in the following paper on Total Heats.

3 "Anyone using Mr. Dodge's data should, however, be warned of the necessity of making certain corrections in the low-side temperatures. The usual radiation corrections, which can be determined from tests which he made for that purpose, are uniformly small, seldom exceeding 5 deg. fahr. But even with these corrections his observations afford strong internal evidence of some other as yet unexplained error, by reason of which the low-side temperatures still run consistently low, by from 13 to 15 deg. fahr., the amount of the correction being almost independent of the circumstances of the tests. A detailed discussion of these observations will soon appear in another place.

4 "In conclusion, the straight-line law of Mr. Dodge's first paper is obviously only a rough first approximation to the truth, and *has no theoretical significance whatever.* This fact needs emphasis because the temptation to amuse oneself with thermodynamic manipulations based on a simple law of that sort is very strong. It is true that the lines on Mr. Dodge's Fig. 6 are very nearly straight, but it is also true that a very small curvature in them makes a very great difference in any conclusions that can be drawn from them by the usual thermodynamic processes. And it can be proved conclusively, both from Mr. Dodge's data and in many other ways, that there actually is enough curvature in them to make the contrary assumption wholly misleading."

Dr. Sanford A. Moss. Mr. Dodge's experiments, as well as the throttling experiments of Grindley, Griessmann and Peake are exactly the same as the "Porous Plug" experiments made by physicists. In any such experiment there is throttled expansion, that is, expansion from one pressure to another without doing any work and without radiation or final velocity, the "total heat" being constant. Under such circumstances, the ideal "perfect gas" would remain at constant temperature. Actual gases under most circumstances cool when they so expand, however, and experiments of the type under consideration give the amount of this cooling.

2 I have made considerable study of the law connecting this matter with specific heat, which forms the basis of the present paper. The following statement of the law is equivalent to that given in the paper:

3 Suppose we have a gas at a given pressure P'' and a given temperature A'' and suppose we have throttled expansion to another pressure P' the final temperature being A'. Next suppose we make a

small addition of heat at constant pressure to the substance when at the original condition so as to give a small temperature increment $B'' - A''$ at pressure P''. Suppose from this latter condition we again have throttled expansion to the previous pressure P', the difference between the final temperatures being $B' - A'$.

4 Since the amounts of total heat were constant during the two throttled expansions, the amount of heat which gave the temperature increment $B'' - A''$ at temperature P' is exactly the same as the amount of heat which would give the temperature increment $B' - A'$ at pressure P'. Hence the ratio of values of specific heat at constant pressure at the two points is the inverse of the ratio of temperature increments. It is, of course, to be noted that the two points whose specific heats are thus related are points having the same total heat, that is, on the same line of throttled expansion.

5 I have plotted a diagram like Fig. 6, with all the points of Table 1, for 15 lb. final pressure. I reduced to exactly the same initial pressure all points with neighboring values of initial pressure, by a formula given later. I find that each of the lines for a given initial pressure is a straight line as nearly as can be judged from the rather irregular points. That is to say, when points from all tests with neighboring values of initial pressure are plotted together as in Fig. 6, a straight line well represents them, instead of a curved line as drawn for the single tests in Fig. 6. From these straight lines I have deduced the empirical laws mentioned later. These laws are all based on the results given in Table 1 and may be considered as mathematical expressions well representing the values of this table.

6 As explained later, the conclusion that the lines of Fig. 6 are straight means that the ratio of the two values of specific heat at the initial and final pressures is constant regardless of the temperatures.

7 The plotted points are so irregular that I question the advisability of selecting specific pairs of points and finding variable ratios for them, as Mr. Dodge does in the last two columns of Table 1. It may be that the lines of Fig. 6 are not exactly straight lines. However, I believe a definite conclusion one way or the other cannot be drawn from the experiments given, owing to their irregularity. Hence straight lines, since they represent the points as well as curved ones, are preferable for simplicity.

8 Since straight lines represent the points, it follows that increments of temperature due to addition of same amount of heat at constant pressure at two given pressures have the same ratio regardless of the temperatures involved. That is, values of specific heat at

two given pressures have the same ratio regardless of the temperatures, the proviso being added, however, that the two temperatures have a relation to each other in that they are produced by throttled expansion between the two given pressures. In other words, the ratio of values of specific heats at any two given pressures is constant for any pair of temperatures such that the total heat has the same value. Hence, if lines corresponding to constant values of total heat of superheated steam be drawn on a curve giving values of C_p against temperatures for given pressures, then the ratio of values of C_p for any one pair of pressures will be the same for each pair of points on a constant total heat line.

9 If the results of throttling experiments are plotted as in Fig. 1, the straight line law means that intercepts between any two lines of "constant total heat" on a pair of constant pressure lines, bear the same ratio to each other. That is, referring to Fig. 1,

$$\frac{A'' B''}{A' B'} = \frac{A'' C''}{A' C'}$$

This ratio is, as already discussed, the inverse ratio of values of C_p for the two pressures (at temperatures corresponding to the same total heat). This is also the ratio of the slopes of the straight lines in the figure similar to Fig. 6. It turns out the actual slopes have very closely the ratio,

$$\frac{C_{p2}}{C_{p1}} = \frac{1460 + P_2}{1460 + P_1}$$

The irregularity of the points makes it impossible to say that they give this law exactly. However, they are closely represented by it. It will be interesting to apply this law to other throttling experiments.

10 If the straight lines mentioned are continued by extrapolation, it turns out that they all intersect at 877 deg. fahr. for both ordinate and abscissa. If this is valid, 877 deg. is the "temperature of inversion" for steam for all pressures. For temperatures above this, there is heating during throttled expansion, such as is well known to occur with hydrogen at ordinary temperatures and which prevented its liquefaction. For temperatures below the temperature of inversion, there is cooling such as occurs with most gases, including hydrogen at low temperatures. Cooling during throttled expansion from high pressures, at temperatures below the temperature of inversion, is the usual means of liquefaction of gases.

11 Of course, this exact value of the temperature of inversion may be incorrect. Even if the lines are practically straight for the region of Fig. 6, they may curve enough to give a higher value.

12 The combination of the two mathematical laws mentioned gives as the relation between pressure and temperature (that is, the equation in Fig. 1) of a line of constant total heat or throttled expansion,

$$(877 - t)(1460 + P) = \text{constant} = (877 - t_1)(1460 + P_1) \qquad (2)$$

Here t is temperature in fahrenheit degrees and P is absolute pressure in pounds per square inch. This relation gives the temperatures at points for which the specific heat ratio (1) holds.

13 Equation (2) is the general law of cooling for porous plug or throttled expansion of steam, and a similar law probably holds with more or less accuracy for other gases. Following are some deductions from this law useful in thermodynamic work or porous plug work such as that of Joule and Kelvin or Rose-Innes.

14 The explicit relation between corresponding drops of pressure in pounds per square inch and temperature in fahrenheit degrees is,

$$t_1 - t = \frac{(P_1 - P)(877 - t_1)}{1460 + P}$$

15 The corresponding differential coefficient or variation of temperature with pressure for constant total heat is,

$$\mu = \left(\frac{dt}{dp}\right)_H = \frac{877 - t}{1460 + P}$$

If the temperature is small compared with 877 and if the pressure is small compared with 1460, as is the case when the initial conditions are nearly atmospheric; or if the initial temperature and the final pressure are constant; then the temperature drop is directly proportional to the pressure drop.

16 For all values of temperature, if the pressure is small compared with 1460 or if the final pressure is nearly constant, we have,

$$t_1 - t = K(P_1 - P)(877 - t_1)$$

17 It is to be remarked that in all of the above discussion, the term "total heat" is used for the total energy which has been put into

a gas to bring it to a given condition. This includes the internal energy actually present as molecular vibration, etc., as well as the energy expended in passing the gas into the region of the given pressure. If we denote total heat by H and internal energy by U and if A is the reciprocal of the mechanical equivalent of heat,

$$H - H_0 = U - U_0 + A\,P\,V - A\,P_0V_0$$

$$C_p = \left(\frac{dH}{dt}\right)_p .$$

Total heat as thus defined is constant during porous plug or throttled expansion.

SPUR GEARING ON HEAVY RAILWAY MOTOR EQUIPMENTS

By Norman Litchfield, Published in The Journal for Mid-November

ABSTRACT OF PAPER

A paper dealing with the breakage of gearing in heavy electric railway service as typified by the equipments of the Interborough Rapid Transit Company, New York, which operates the Elevated and Subway lines. A résumé is given of the methods employed to overcome the breakage, and the strains in the teeth as calculated by the Lewis Formula are shown. Attention is called to the fact that this formula is not entirely applicable on account of the difficulty in maintaining alignment of gear and pinion.

DISCUSSION

Mr. F. V. Henshaw. Gearing for large railway motors offers problems worthy of study by specialists in steel-making and experts in gear-design. Mr. Litchfield contributes some data thereon, derived from what is, considering all conditions, probably the limit of hard service on spur gear drives. Railway motors are limited in dimensions by unchangeable conditions, the fundamentals being largely the same on great railroads and on street car lines. The available space is ample for the small motors (25 to 60 h.p.) required by the latter, gears of liberal dimensions can be provided, and the mechanical problem is confined to reducing wear: in designing motors of 150 to 200 h.p. under the same general limitations, however, the conditions are so far reversed as to require a new departure in gear practice.

2 The situation is illustrated by the following data from three typical cases in practice. The calculated values are in round numbers and based on rated loads at 500 volts. Incidentally, while horse power ratings have much the same meaning in the case of railway motors as when applied to steam boilers, yet they serve the present purpose as a fair measure of the maximum working torque.

TABLE 1 DATA OF TYPICAL RAILWAY MOTORS IN NEW YORK

Specifications	Surface Car	Manhattan		Subway
Horse Power	40	125		200
R. P. M. Armature	500	560		500
Torque, inch-pounds	5000	14000		25000
Torque, pounds at p.d	1770	4670		6250
Feet per minute " "	740	880		1045
Pitch	3	3	2.5	2.5
No. Pinion Teeth	17	18	16	20.
Face, Gear and Pinion	5	5	5	5.25
Sq. in. Tooth at p.d	2.62	2.62	3.14	3.3

3 A committee of the A. S. & I. Railway Association has recommended the following gear sizes as general standards:

For motors of 45 to 100 h.p., 3 diametral pitch, 5 in. face
" " " 100 " 250 " 2.5 " " 5.25 " "

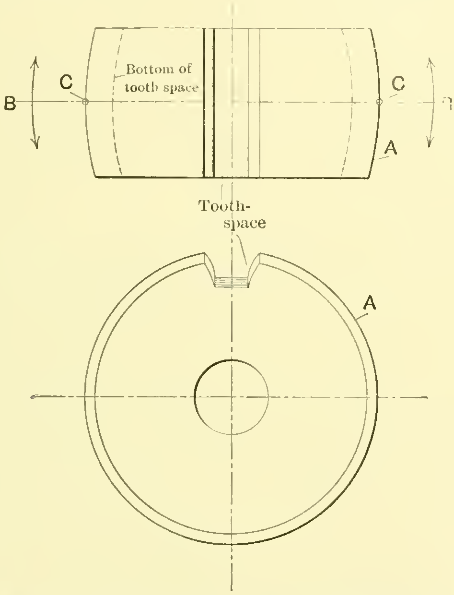
4 In short, owing to various limiting conditions, there is no kind of proportion between the motor capacities and the gear dimensions in use. The conditions for large motors are even more severe than indicated above as they actually run on higher voltages and consequently at higher speeds than stated; this fact accounts for the higher pinion velocity given by Mr. Litchfield. By the use of interpole motors with forced ventilation still greater motor capacity can be obtained with the same available motor space so that cases may arise in which gear-strength will be the governing factor in large motors.

5 As to the solution of the problem, three suggestions are quoted in Par. 10, and the author offers a further suggestion in Fig. 6 for overcoming the inevitable lack of shaft alignment. The first suggestion is the use of a coarser pitch and any possible misconception of the situation may be cleared away by the broad statement that any improvement involving reduced gear-ratios or increased gear-diameters may as well be ruled out. The highest practicable gear-ratios are none too high for many cases, there is little or nothing to spare in reducing either the number of teeth or the diameters of pinions, gear cases have no clearance to spare, and we cannot help the situation by using larger wheels. It appears then that the solution of the problem of satisfactory gearing for large railway motors must be looked for in the material and form.

Mr. John Thomson. The accompanying diagram (Fig. 1) indicates a solution of the problem in Par. 20 of this paper, that can

readily be accomplished by the use of ordinary gear-cutters. This consists in curving the periphery of both the pinion and its gear, each blank thus becoming a spherical zone, as *A*. Then when forming the leaves of the gear, either the blank or the cutter is to be swung in the arc of a circle corresponding to that of the peripheral surface, say as *B*, with *C* as the axis.

2 The consequence of this would be that in first starting the operation of such a pair of gears, there would be point-contact only at their centers; but as these wear away the area of contact would



PROPOSED METHOD FOR SECURING CONTACT BETWEEN TEETH AND A CENTRAL PLANE

increase. When using involute contours, I do not see that this would affect the action; detrimentally on the contrary as new surfaces were brought into contact the pitch-ratio would be maintained constant. Moreover, incorrect initial alignment, or that resulting from wear and tear in practice, would seem to be met automatically.

3 I have not tried this method and the idea is an off-hand shot; but if it is worth the while, anyone is welcome to use it.

MR. J. KISSICK, JR. There is, to the writer's mind, a remarkable similarity between the problems of the elevated and of the subway

service. The greater part of the problem will be solved for both when the prolongation of the life of the tooth is accomplished: in this respect the two problems are similar.

2 On the elevated division the introduction of the wrought steel rim gear and the adoption of a $2\frac{1}{2}$-diametral pitch has solved the question of breakage, thus leaving the brief wearing-life of the teeth as the final obstacle to be overcome.

3 Experience on the elevated road naturally caused the adoption of similar gearing equipment in the subway, although with different results. Here, we understand, the trouble seems to be breakage in the pinion teeth, and to a lesser extent in the gear teeth. Since it has been deemed unsafe to run a pinion which has worn to $\frac{3}{16}$ in. at the top, it is obvious that any remedy which will prolong the wearing-life of the teeth will also prevent the large number of failures due to a high fiber stress induced in the worn tooth by the accelerating torque.

4 Mr. Litchfield has considered the problem, it seems to the writer, merely as one of a cantilever beam, the tooth being loaded at the crest and supported at the root. Being a case of simple flexure, one needs but to vary one or all of three things to enable the tooth to support a given load:

a Increase the depth of the beam, which, however, would be at the expense of the meshing tooth, although by increasing the angle of obliquity, as in the 20-deg. involute stub tooth, the tooth may be thickened to a certain extent at the root.

b Increase the elastic limit, which has been accomplished by the substitution of wrought rim gears.

c Decrease the moment by shortening the lever arm of the load, which has been brought about by the use of stub teeth.

5 Were the problem one which concerned the supporting of a static load, the above remedies would be sufficient; but being also a gearing proposition, other factors enter in that have to be met. There is no doubt that the use of steel having an elastic limit of 90,000 lb. per sq. in. and the use of 20 deg. involute stub-teeth, while they have not eliminated all the trouble, have at least caused it to appear in mitigated form. The difficulty seems to be that these remedies do not go far enough, and do not treat the problem from a gearing standpoint as well as from that of a loaded beam.

6 An extended experience covering railroad work and crane serv-

ice (in the latter case breakages of ordinary cast steel gears and pinions causing a menacing situation) has brought to light several factors not ordinarily considered as affecting the strength of gear teeth.

7 The first of these is resistance to wear. This, of course, needs no explanation, for it can be very easily realized that with a thick tooth there is less chance of failure than with a tooth which has been worn thin.

8 The second is permanency of form and resistance to deformation, the two being more or less related. Ordinary conditions of construction and service preclude any possibility of theoretical engagements of involute teeth, and we have the substitution of sliding for rolling motion. The result, naturally, is abrasive action, which ordinary steel gears are unable to withstand; the tooth curve below the pitch line becomes flattened and slightly undercut, the amount depending upon the smallness of the pinion and consequent obliquity of action. The loss of the involute curve and the additional back lash destroy the intended action of the tooth, and instead of one set of teeth taking the load before another lays it down, we have one set carrying the whole load and transferring it bodily to the succeeding set at some point near the pitch point at the rate of some 1800 blows per minute. The effect of this hammering is commonly called "wear," but nothing could be further from the truth. No ordinary steel could stand up under these blows, and consequently we find the metal flowing towards the edges and top of the tooth, depositing small slivers eventually in the gear case. An examination of the accumulation at the bottom of the tooth would show these slivers, and also a deposit somewhat similar to anvil scale.

9 The fact is that the ordinary steel gear does not wear, in the true sense of the word. Its inability to keep its shape under the severe hammering exaggerates the fault as time goes on, and premature failure is the final result. The use of stub-teeth does not help this condition any, for even the most perfectly cut tooth of this design transmits power with a very jerky motion.

10 A new steel pinion placed in service with a half-worn gear does not exert a corrective effect on the gear tooth, but instead, falls a prey to the evil tendencies of the gear. The problem therefore might be stated as follows:

a A $2\frac{1}{2}$-diametral pitch 20-deg. involute stub-tooth affords a very strong tooth design.

b Metal to withstand 90,000-lb. fiber stress at the elastic limit is essential.

c The material comprising the tooth, in addition to sustaining the above fiber stress, (1) should be proof against wear by abrasion; (2) should offer maximum resistance to deformation, thus retaining as long as possible its original form; (3) should not be brittle, or fracture under repeated blows.

11 The latter clause really means the substitution of a special steel. Manganese steel fulfills all the requirements, being tough and extremely hard, and having an extremely high elastic limit.

12 Its wearing properties are well known, for it is the only metal which can be used successfully in crushing-machinery, and in fact in all places where abrasion takes place. Its resistance to deformation is one of its peculiar characteristics, limiting its use in ordinary commercial work, but making it particularly valuable for the service under discussion. It has been demonstrated in comparative tests that the more prominent this characteristic is, the longer the life of the gear. Where the gear was made very soft, the size of the burr on the edge of the tooth was, to a certain extent, inversely proportional to the length of service.

13 The early considerations affecting the designs of manganese gears were naturally foundry ones, which required an even and comparatively thin metal section. Experience has overcome the casting difficulties, however, and the manufacturers have been able to turn their attention to the character of the work required of their product.

14 It is the writer's firm conviction that the use of manganese steel gears, properly designed, will solve this particular problem.

Dr. George William Sargent. Much stress has rightly been laid upon the desirability of stronger material that the motor equipment of the subway may obtain relief from its present gear and pinion troubles. Resistance to wear seems to me of the greatest importance in modifying the stresses to which the tooth of the gear or pinion is subject. Wear on the teeth develops play, with a consequent change in the character of the stresses. The load which was delivered statically is now delivered dynamically and must be reckoned upon as a blow. Energy expended in the form of blows tending to rupture a piece of steel is much more destructive than the same energy gradually applied. Hence the utmost resistance to wear is a desideratum as much to be sought as increased strength; and do not the nature of the breaks described in Par. 17 prove this to be the case?

2 Fig. 3 is illustrative of all the failures. "It will be noticed that points *a*, *b*, *c*, *d*, and *e* gave way successively until at last the loose piece was caught and ripped out." (Par. 17.) Such a break produces a detailed fracture not inconsistent with the statement that, as wear increased the play, thereby causing greater severity of the blows, the tooth began to rupture, ruptured in a small degree, then in a larger degree, and at last completely. To prevent absolute failure, resistance to wear is of the utmost importance, and this leads to a consideration of hardness as a quality determinative of ability to withstand abrasion or wear.

3 It is well known that as hardness in steel increases, brittleness develops, hence there is a hardness limit beyond which, on account of the product's lack of toughness, it is not safe to go. This limit varies with each kind of steel. The carbon steels have the lowest values for hardness and toughness at this limit, thus a 45,000 lb. per sq. in. elastic limit carbon steel has a hardness of 191 (Brinell scale), a 90,000 lb. per sq. in. elastic limit carbon steel a hardness of 286, and 140,000 lb. per sq. in. elastic limit alloy steel a hardness of 400. In the first instance the values are about the maximum obtainable from an ordinary carbon steel; in the second from an extraordinary carbon steel; and in the last instance the values might be raised a little before the point of safety would be exceeded. Although it is obvious which steel is superior, consideration of the lives of the gears made from the respective steels may make it yet clearer.

4 Assuming, although it is not by any means the case, that a body twice as hard as another will resist wear twice as long, a gear made of the extraordinary steel, with its elastic limit double that of ordinary steel and its hardness increased 50 per cent, should have its life doubled on account of its increased strength and made half as long again on account of its increased resistance to wear, making a total increase in the longevity of the gear of two and one-half times. With the alloy steel gear, reasoning after the same manner, the life will be increased over that of the ordinary steel gear twice by the hardness and three times by the strength, a total of five times. These figures are too low for the facts, but they show relative values and the importance of the matter of hardness. It is stated that in practice it is impossible to maintain perfect alignment between gear and pinion. Too great hardness is therefore to be avoided, since the points of contact might be made too few, bringing excessive strain upon these few points, with the resultant rupture.

5 Failures of machines in service usually result from one or more

general causes, two of which are, improper design and failure to select the proper constructive material. These are usually due to a lack of appreciation of the conditions of service, although they may be due to the development of changed conditions of service. The design may be correct and the material of construction right and either improper methods of handling the material or imperfect manufacture of the material or both may yet bring about failure. Judging from the fact that the factor of safety is but 1.1, and a change in the design raises this factor 1.6, both improper design and the failure to select proper constructive material seem to be responsible for the conditions. That this is the case is further indicated by the character of the fracture described in Par. 17 as typical of all the failures.

6 It is in just such instances that the alloy steels, with their greater possibilities, find their usefulness. Increased dimensions are not permitted, altered designs effect but a partial relief, and a harder and stronger constructive material must be used. True, these alloy steels are more expensive in their first cost, but really less expensive in the final reckoning. Where life hangs in the balance, cost should be not even a secondary consideration.

Prof. F. De R. Furman. Mr. Litchfield's suggestion of giving the tooth a double-curve form can hardly solve his problem, for it will still leave the entire load of the teeth concentrated on point contact under all conditions. If the contact point should move to one side, due to improper alignment of the wheel shafts, the pressure would come at a reduced and therefore weakened section.

2 Using the data given in this paper, I have laid out the proportions of teeth obtained by standard rotary cutters (according to proportions given in Kent) for both 14½-deg. and 20-deg. pressure angles, which the author states were used, and then compared these teeth with others of special form which figure out to be much stronger. The comparative forms are shown in Fig. 1 and 2, in which teeth of standard proportions are shown entirely in section, the proposed form with shaded edges. In Fig. 1 the 14½-deg. pressure angle is used, and in Fig. 2 the 20-deg. angle.

3 I have made the comparison by considering the tooth as a beam fixed at one end, and have drawn within each tooth a parabola having its vertex at the middle of the crest and its two branches tangent to the outline at or near the root. Then applying the formula $hP = \frac{1}{6} Fbt^2$, in which h = height of tooth, P = pressure on tooth at the tip, F = working stress in tooth, b = breadth of tooth (taken as 3 in.).

and t = thickness of tooth, we have for F = 39,400 lb. (the figure given by Mr. Litchfield), P = 7700 lb. for the standard tooth having a 14½-deg. angle. For the proposed tooth with the same angle, taking P = 7700 as above, we find F, the stress at the root = 23,600 lb., against 39,400 for the standard tooth, an increase in strength of 67 per cent in favor of the special form of tooth.

4 For the tooth with a 20-deg. angle we find for the same value of P (7700 lb.) that the stress in the standard tooth is 35,600 lb., against 25,600 lb. for the proposed tooth, an increase of 39 per cent. While

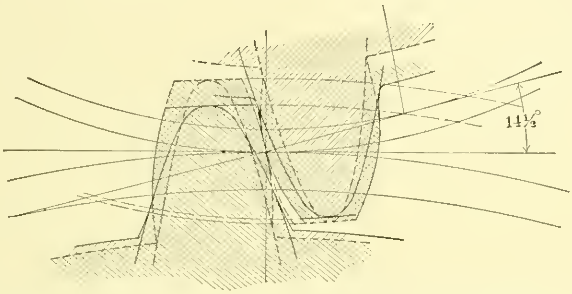


Fig. 1 Comparison of Tooth Forms 14½ Deg. Angle

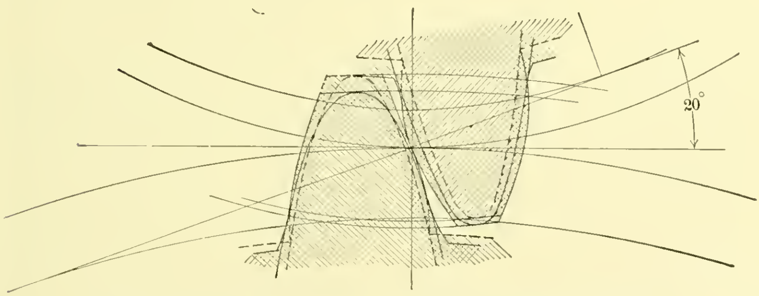


Fig. 2 Comparison of Tooth Forms 20 Deg. Angle

the 20-deg. tooth shows up the stronger for the standard form, the 14½-deg. tooth is the stronger in the proposed form. This is due principally to the decreased length of tooth for a given path of action, made possible by the 14½-deg. angle, and also to the specially formed fillet which starts from a point well up from the root circle.

5 The amount of action in the 14½-deg. proposed tooth is about 1.5, practically the same as for the standard form, assuming that that part of the standard tooth which is above the interference line is not in action.

6 The large fillets at the roots of the proposed teeth were found by tracing the path of the corner of one tooth on the plane of the other wheel and then placing the tooth outline within this path. The parabola was then drawn tangent to the tooth outline. In making the above computations the weaker tooth on the smaller wheel was used in each case.

7 It will be noticed that the addenda for the two teeth are not equal, a point referred to in my discussion of Mr. Flanders' paper.

The Author. It was not the purpose of the writer to attempt to approach this subject from the standpoint of the gearing-expert but merely from that of the user of a considerable amount of gearing material on an exceedingly intense service, and to lay before the Society those encountered difficulties which might be of interest, together with the efforts made to overcome them.

2 While it is impossible to take up the discussion in detail, in the limited time allowed for review of the various points, correction should be made of a seeming misapprehension on the part of one writer who states: "There is no doubt that the use of steel having an elastic limit of 90,000 lb. per square inch and the use of 20-deg. involute stub-teeth, while they have not eliminated all the trouble, have at least caused it to appear in mitigated form."

3 At the time of the preparation of the paper practically none of the gearing under our observation was of the stub-tooth, high elastic-limit type, and while since then a large number have been installed, the length of service has obviously been too short for judgment of the value of the improvement.

4 Much stress is laid by others on the value of alloy-steels, and it should be stated therefore that the attractiveness of several of them has been such as to lead to a thorough investigation of their merits, which is still under way. These investigations include actual service tests in quantities large enough to give a fair indication of results to be expected from a general adoption of the particular class of steel in question. Until these data, coupled with those yet to be found for the treated carbon-steel, are obtained, it would be improper to discard the carbon-steel and adopt the alloy.

5 Aside from the question of the tooth form the situation may be thus briefly summarized:

The carbon-steel has failed and data must be obtained from service of the resistance to failure of (1) Specially treated carbon-steel; (2) Alloy steel.

If one shows a manifest superiority over the other, then that should be adopted, but if they compare favorably, the problem will then have changed from one of failure to one of wear, and we will at the same time be in possession of the information necessary to determine this second phase of the question of gearing on heavy railway equipments.

INTERCHANGEABLE INVOLUTE GEAR TOOTH SYSTEMS

By Ralph E. Flanders, Published in The Journal for Mid-November

ABSTRACT OF PAPER

This paper gives diagrams showing the effect of varying the pressure angle and addendum on the various practical qualities of gearing, such as interference, number of teeth in continuous action, side pressure on bearings, strength, efficiency, durability, smoothness of action, permanency of form, etc. After comparing typical examples of interchangeable gear systems in these particulars, the author concludes that a new standard for heavy, slow speed gearing is advisable.

DISCUSSION

Mr. Wilfred Lewis. I think Mr. Flanders has presented a very illuminating and complete analysis of the conditions governing the intelligent use of interchangeable involute gearing from a 12-toothed pinion to a rack. It appears from this that the so-called standard $14\frac{1}{2}$ deg. system is really no system at all, but rather an evolution by a sort of trimming process from the errors of the past.

2 About thirty years ago when I first began to study the subject, the only system of gearing that stood in much favor with machine tool builders was the cycloidal in which the describing circle was made one-half the diameter of a 12-toothed pinion, thus giving it radial flanks. At that time I was called upon to investigate a cutter forming machine in which the faces and flanks of the cutter were approximated by circular arcs. I soon came to the conclusion that the true form of such cutters could not be approximated by circular arcs near enough to give satisfactory results, and I worked out a scheme whereby the machine was modified to form the faces and flanks each by two tangent arcs instead of one. Some improvement in action resulted from this change, but the gearing produced was still noisy, and this improvement was followed by the very radical one of building a cutter forming machine in which the shapes produced were actually rolled.

For some time thereafter Wm. Sellers & Company, with whom I was connected, continued to use cylindrical gearing made by cutters of the true shape, but the well known objection to this form of tooth began to be felt, and possibly twenty-five years ago my attention was turned to the advantages of an involute system. The involute systems in use at that time were the ones here described as standard, having 14½ deg. obliquity, and another recommended by Willis having an obliquity of 15 deg. Neither of these satisfied the requirements of an interchangeable system, and with some hesitation I recommended a 20 deg. system, which was adopted by Wm. Sellers & Company and has worked to their satisfaction ever since. I did not at that time have quite the courage of my convictions that the obliquity should be 22½ deg. or one-fourth of a right angle. Possibly, however, the obliquity of 20 deg. may still be justified, by reducing the addendum from a value of one to some fraction thereof, but I would not undertake at this time to say which of the two methods I would prefer. In a general way I think Mr. Flanders has raised a very important question, and one which should be taken up by the Society.

3 I brought up the same question nine years ago before the Engineers' Club of Philadelphia, and said at that time that a committee ought to be appointed to investigate and report on an interchangeable system of gearing. We have an interchangeable system of screw threads, of which everybody knows the advantage, and there is no reason why we should not have a standard system of gearing, so that any gear of a given pitch will run with any other gear of the same pitch.

4 I would therefore propose as the author suggests, that this subject be referred to a Committee of the Society to investigate and to report upon the adoption of a standard system of involute gearing. The paper considers gears from a 12-tooth pinion to a rack only, and that is as far as I would go with such a system. If internal gears are employed, they would necessarily have to be more or less special. I think Mr. Flanders has covered the subject in a very clear and concise way. He has done a great deal towards the solution of the question by properly stating it, and when anything is properly stated, it is half solved. I therefore make this a motion. (The motion was considered later in the discussion.—Editor.)

Mr. Luther D. Burlingame. I can easily believe that my friend, the author of this paper, found the solution of the interchangeable gear tooth problem a task far greater than he had anticipated.

While many writers appear to reach some rather definite conclusions, I believe that the usual experience of investigators along these lines has been voiced by Mr. Fred J. Miller in the American Machinist, "I think that it is the experience of most men that the more they have studied on the matter of tooth-gearing, the more clearly it has appeared to them that they would never be able to believe anything in regard to it." I take this opportunity to express my appreciation of the able and fair-minded way in which Mr. Flanders has dealt with so difficult a subject, and one that can be viewed from so many points.

2 Mr. Flanders bases his data for the $14\frac{1}{2}$-deg. pressure-angle entirely on a form of tooth which is a true involute for its entire length. As such a tooth is not made or recommended by any manufacturers, as far as I know, and as what is made would give a radically different showing in the comparative tables of the paper, this seems to be setting up a "straw man" to knock over, rather than "tackling" the real thing. It can be said in extenuation that the author used the data at hand; that the data in commercial use were not available is not surprising, as they have been derived by manufacturers through years of experience and at great expense; furthermore, the giving out of such data, even were it good policy, most probably would never result in the production of good gears, much less of interchangeable gears. The experience of the company with which I am connected is that the old saying, "a little knowledge is a dangerous thing," is most applicable to the science and practice of gearing.

3 In illustrating the difference between the theoretical and the commercial tooth of $14\frac{1}{2}$-deg. pressure-angle, reference is made to Par. 7, 10 to 19 inclusive, 33, 37, and 38, and to Fig. 5, 8, 12, 13, and 14, as well as to the table accompanying Par. 45, Comparison of Selected Examples of Involute Gear Tooth Systems. These deal to a greater or lesser extent with the question of length of contact of the engaging teeth and with the question of the number of teeth in continuous action. To show the radical difference between the results obtained in the paper and based on the use of the uncorrected involute form of tooth with $14\frac{1}{2}$-deg. pressure-angle, inadvertently called by the author the Brown and Sharpe system, and the results actually obtained with cutters made by that company, I would refer to Fig. 1 to 3. As a matter of fact there are two teeth driving for half of the time, or on a basis of Mr. Flanders' table referred to above, 1.5 teeth in continuous action. As his table gives 0.98 of a tooth in continuous

action, the real Brown and Sharpe tooth shows a gain of more than 50 per cent above the results tabulated as the Brown and Sharpe standard. If all of the statements in paragraphs and figures above referred to should be modified to this extent, they would give a real comparison instead of a hypothetical one. Thus referring to Fig. 14, Case 1, the diagram would be radically modified for the Brown and Sharpe system where at least two teeth are driving for half of the time, the commercial tooth approaching nearer to what is shown in Case 5 of this same figure.

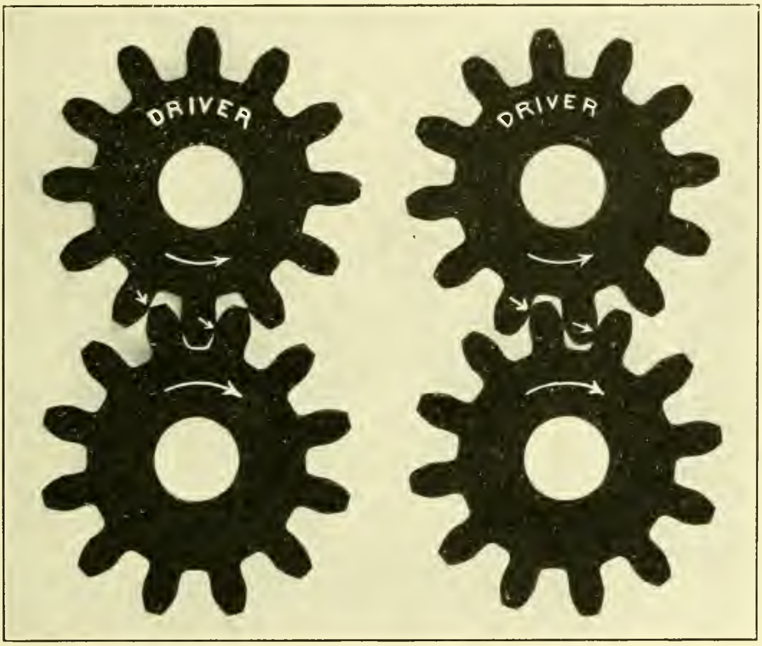


Fig. 1 — Twelve-Tooth Pinions B. & S.

Fig. 2 — Interchangeable $14\frac{1}{2}$-deg. System

4 The teeth of the gears cut with Brown and Sharpe cutters are slightly eased off at their points so as to come gradually into engagement, thus insuring smooth and quiet running. Experience has shown that such a modification is not only important but essential, and in any system, no matter what the pressure angle and height of addendum, I believe the teeth should be so modified. When such a modification is made it becomes a mere academic contention whether the corrected part is modified from a true involute or something else.

I understand there are methods covered by patents for accomplishing a rounding and easing off of the points of the teeth when they are formed by the generating process.[1]

5 The impression is given by the author that there are difficulties in the way of using the generating process which limit it and that the devising of a new system of gearing will make its use more satisfactory. This seems like a case where, as the mountain will not come to Mohammed, Mohammed must go to the mountain. To consider

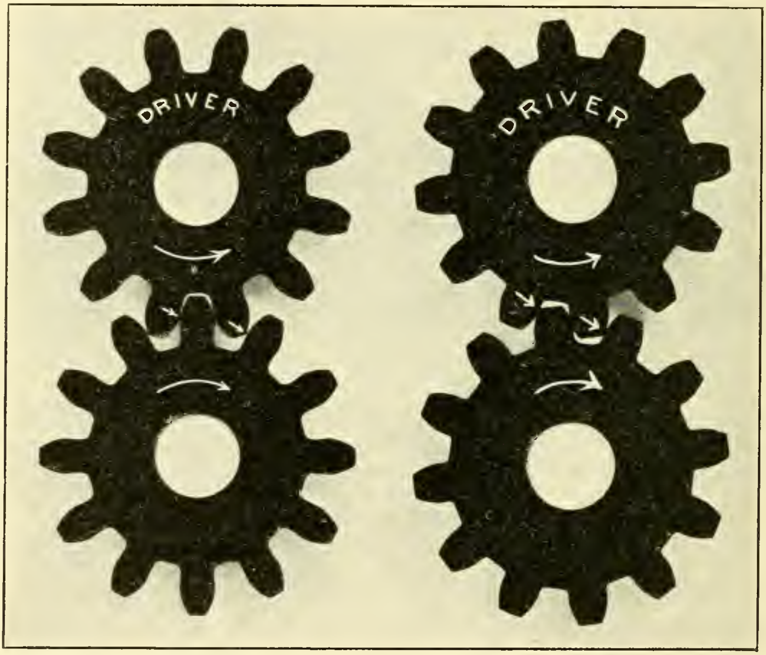


Fig. 3
Brown and Sharpe Interchangeable 14½-deg. System

Fig. 4
Pressure Angle 20 deg. Depth 0.7 Pitch

the adoption of one system for gears made by the generating process and another for those made by the use of formed cutters, would be like adopting the metric sytem for calculations and the English system for the use of the workman, considering each as adapted respectively to these particular uses.

6 In the Brown and Sharpe practice, to meet their own needs and those of their customers, cutters and gears are made with pressure

[1] Bilgram Patents No. 749,606 and No. 749,683.

angles varying from 4 to 28 deg., and with a height of tooth ranging in both directions far outside of the limits discussed in Mr. Flanders' paper. It is an everyday matter to produce gears and cutters with such variations, and they can be made at least with equal facility, as compared with standard shapes, by the use of formed cutters. Such cutters, as made by Brown and Sharpe for 20 and 22½-deg. pressure-angle, are for each angle interchangeable.

7 Mr. Flanders has given little consideration to the question of *backlash*, in fact has not mentioned it in Par. 45, where he sums up the objections to using a greater pressure-angle and less addendum. In many classes of work this becomes an important consideration and any system tending to increase backlash is objectionable. It is a common practice in making special gears for printing presses and other places where backlash must be reduced to a minimum, especially where the center distance of the gears must vary appreciably, to make the pressure-angle as low as 4 deg. and to increase the addendum to a greater length than standard. In any case, the greater the pressure-angle the more backlash there will be with a given inaccuracy in center distance, a given variation in setting the cutter or tool when producing the gear, or a given amount of wear on the teeth.

8 There are indeed special cases where a greater pressure angle than 14½ deg. is sufficiently desirable for various reasons to off-set the objections made. The Brown and Sharpe Company use on their machines gears with a greater pressure-angle, when the conditions make it seem desirable, and they make such gears and cutters for customers whenever called for. These, however, are invariably made with a correction for smooth and quiet running, even when the pressure angle and height of tooth are such that theoretically this would not be required.

The Reinecker generating machine has provision for easing off the points of the gears to prevent noise.

9 Frank Burgess of the Boston Gear Works says[1] regarding the height of tooth, "A long tooth usually gives a better movement than a short stubby one. With the shorter tooth, the pitch is proportionately greater for its depth and there is a tendency to jump from one to the other, especially for a pinion with less than 20 teeth, and this tendency results in noise. The noise in gearing is undoubtedly the result of shocks, jumps and vibration caused by teeth coming into and going out of action."

[1] American Machinist, June 27, 1907, p. 935.

10 While the use of shorter teeth or a finer pitch would theoretically make some saving in time of cutting, we do not find such a saving appreciable.

11 I would ask the author why the possibilities of inaccuracy mentioned in Par. 30 as applying to the use of formed cutters are not also present in the generating method, instead of being limited as stated in Par. 31. It would seem to me that most of these possibilities of inaccuracy would be equally present in both systems.

12 With all our experience at the Brown and Sharpe works, our experts feel that the subject of gearing is full of pitfalls, and the more experience we have, the less we feel like dogmatizing or appearing as authorities. While all theories should be examined with an open mind, I believe that a spirit of conservatism should govern their investigation until they are proved by practical experience to be correct.

13 I do not understand that the author suggests an abandonment of the present system, but states rather that the "discussion points clearly to the wisdom of an alternative gear tooth standard of shorter addendum and increased pressure angle." The fact is that modified forms of teeth, of a sort approved by the author and many other forms also, are now used in special cases where they prove to be better. Every manufacturer of gear-cutters knows this to be true, though at the present time, with the large demand for gears in automobile construction, there may be an emphasis upon a tooth of a certain form. What this emphasis will be in future years is uncertain. As likely as not another pressure-angle and another form of tooth may be insisted upon. Is it not better to leave these matters to the manufacturers of gear-cutters and gear-cutting machines who are willing to give the public what they want rather than attempt to formulate a system which the experience of the next few years may possibly render of little value?

Mr. D. F. Nisbet. I agree fully with the author's conclusion that an alternative standard of involute teeth for heavy, slow-speed gearing is desirable; particularly so for such gearing as rolling-mill pinions, where, owing to the limited diameter and tremendous shocks, it is necessary to use few teeth of large pitch, and obtain a comparatively smooth action by making the gears either double helical or of the staggered tooth type.

2 Smoothness of action, as understood and defined by builders of the finer classes of machinery, is not essential for rolling-mill work;

perhaps continuity of action would better express the desideratum for this class of work. All that is necessary is a degree of smoothness of action that will not leave traces of "harsh gearing" on the finished product. This applies with particular force to plate mills and sheet mills, and in a lesser degree to all types.

Mr. Charles Wallace Hunt. It should be borne in mind that this paper treats of a system of interchangeable gears; that is, all of the pinions and gears of each series having the same addendum. This commercial requirement eliminates the consideration of theoretically perfect forms of conjugating teeth for special conditions and confines the discussion to what Mr. Wilfred Lewis designates as the "best compromise between conflicting conditions."

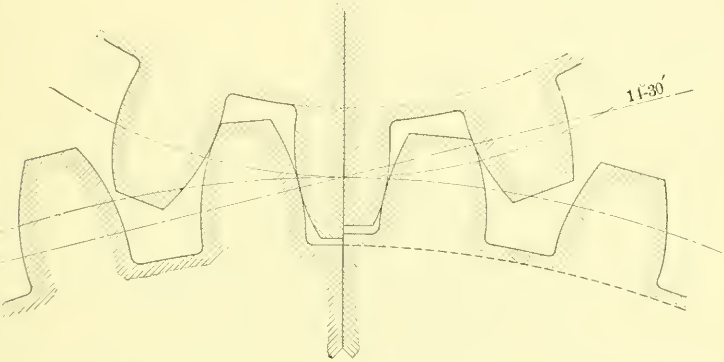


Fig. 1 Diagram Showing Long and Short Teeth with the Pitch-Line in Common

2 Perfectly formed teeth are seldom made and cannot long be maintained owing to wear of the tooth faces. The chief disturbing factors are the shop errors in the pitch diameters of the gears and in the shaft center distances. Such construction errors are unavoidable and so must be tolerated. Some factors partially offset each other, such as the tension caused by the friction of the sliding surfaces of the tooth after passing the center which weakens the tooth. The fillet at the root of the tooth strengthens it. Usually the favorable and the adverse factors partially balance each other, but the working formulae must provide for the unexpected which, as Prof. Sweet reminds us, frequently happens. After considering and valuing the various factors that affect the problem, the designer will decide on proportions that, in his judgment, will give the best general result in practice.

3 In the gear work of the C. W. Hunt Company it is assumed that
The angle of action is 14½ deg.
The whole load is carried on one tooth.
A pinion with less than 19 teeth should not willingly be used.
If the pinion is strong enough its conjugating wheel is also.
A table is quicker and safer to use than a formula.
A table based on fibre stress is preferable to one based on the names of materials.

4 The total length of teeth frequently referred to, expressed as a percentage of the circular pitch, is

Rankine	0.75
Sir Wm. Fairbairn	0.70
Brown and Sharpe	0.687
Molesworth	0.66
Coleman Sellers	0.65
Hunt	0.55

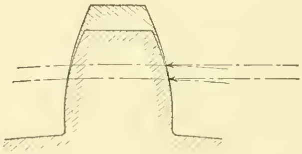


Fig. 2 Diagram Showing a Short Tooth Superimposed on a Long Tooth with the Root-lines in Common

5 After ten years' use in a wide range of machinery, I believe that for commercial machinery the following proportions for cut teeth are especially suitable ones. If they are not ideal proportions the difference is slight. The face of the tooth is involute in form, the angle of action is 14½ deg., and the length of the tooth is 0.55 of the circular pitch.

HUNT TOOTH FORMULA

Addendum	0.25 of the circular pitch.
Dedendum	0.25 " " " "
Clearance	0.05 " " " "
Length of tooth	0.55 " " " "

TABLE 1 WORKING LOADS
Spur Gears, one Inch Face

Diametral pitch	1	1¼	1½	2	2½	3	3½	4	5	6	7	8
Circular pitch	3.14	2.51	2.1	1.57	1.25	1.04	.897	.785	.628	.524	.449	.393
Pounds on the pitch line	2250	1800	1500	1100	900	700	600	565	450	375	300	282

6 Table 1 gives the working strength of a spur tooth, having parallel flanks. The tabular load applied on the pitch line produces a fibre stress at the root of the tooth of 5000 lb. per square inch. If applied at the pitch line plus one-half of the addendum then the fibre stress will be 7100 lb. If at the extreme end of the tooth 9200 lb. per square inch.

7 For a safety factor of $3\frac{1}{2}$ when the load is applied at the end of the tooth:

Cast iron (16,000 lb. ultimate strength), use a working load of one-half the tabular number.

Steel (64,000 lb. ultimate strength), use twice the tabular number.

GEAR CUTTERS

8 The initial stresses in the casting frequently cause a distortion when the gear is finished. A spoked gear-wheel blank may be turned

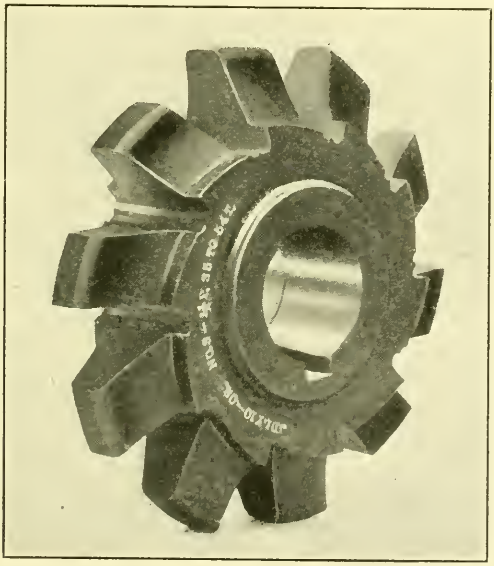


Fig. 3 Perspective View of the Cutter

perfectly round in a lathe, but after the stocking cutter has been used the points of the teeth are seldom in a true circle. The rim between the spokes either bulges out, or falls in, depending on the initial stresses in the metal. This is frequently a material amount

and is objectionable as it alters the pitch line and the tooth spacing, and also injuriously affects the clearance.

9 It has been found advantageous to have tooth cutters (Fig. 4) with a wing on each side which will trim the length of the teeth to the standard size. With these cutters a gear made of metal without a hard scale can be cut without sizing the blanks in a lathe.

10 Cutters for teeth proportioned by the above formulae are made for any one desiring them, by Brown and Sharpe, Gould and Eberhardt, or any other gear-cutter maker.

Mr. Oberlin Smith. The suggestion has been made that a committee be appointed to standardize gear teeth, with the assumption that there would be one standard. Another has said that it is best to leave it to the makers, as they know the needs of their customers; the result of this would be forty, or fifty or even a hundred standards, as we have now. It would seem wise to standardize the teeth, even if there should have to be several kinds. We need to do this almost as much as we needed to standardize the screw thread. It would be useful to have some standard which most people would follow, and undoubtedly in this way a standard practice could be established. The committee would consider the different conditions, as for instance, those met in heavy rolling-mill work, and choose different pressure-angles adapted to each case.

2 If a committee is appointed to consider this matter, I hope they will take out fractions and make the angle of obliquity 15 deg. rather than 14.5 deg. Suppose they found 15 deg. good for a certain class of gears, and 20 deg. good for another class, and 25 deg. good for another class, why could we not have two or three standards, under certain names, so that people could use them to comply with the conditions?

3 If we do have a committee on gearing, their investigations should go further than merely determining shape. It would be well to instruct them to find out all they can about strength of gears as well. The matter of strength is very important, and it is a thing which we do not know very much about. Many of us go by the Lewis formula, by which, it seems to me, the required strength increases too rapidly with increase in speed. But there are conditions of impact and percussion which cause the teeth to vibrate and make them break at high speed. We do not know what these conditions are, and that is what the committee should find out.

4 One thing desirable, in interchangeable gearing, is to be

able to use fewer teeth in pinions. Some one said that nine is the lowest number desirable. The Brown & Sharpe Mfg. Co. give twelve as the least practical number to get a theoretically good wheel, and very likely that is so. I have used pinions with four, for some 15 or 20 years, without perceptible wear where the pressures were not great but the speeds were very high, the small pinion being the driver. I have some lathes which have five-tooth pinions doing the driving; they are still in use and are a perfect success. Of course, it is probable that the angular motion is somewhat irregular with such a small pinion.

5 It is often practicable to use a pinion with from five to ten teeth, as a driving but not as a driven gear. It is well to avoid "strain" of several gears by using only two, having the pinion as small and gear as large as possible. It is often good practice to cut such a pinion in the solid shaft. We are building some heavy presses, of 1000 tons capacity, where the pinions are more than a foot in diameter, forged integral with the shaft, one at each end. A common practice in rolling-mills is to use two helical pinions separately keyed on, with pitch reversed to avoid end-thrust and ends abutting. I recently built a mill for a foreign government, with two 16-tooth pinions forged solid with their shafts where two projecting collars served as blanks for the pinions, and by the simple expedient of separating them, left room for a Brown & Sharpe cutter to run through, into the space between.

Prof. W. Rautenstrauch. It seems as if there were sufficient interestin the principles of machine manufacture to justify the formation of a section to consider papers of this kind and draw fire along this line. I have had the matter in mind for some time, and have talked with other members, and it seems to meet with approval. I therefore propose that we meet this afternoon to consider the formation of such a section, and draw up a letter petitioning the council to form such a section immediately. (The meeting was held and a committee appointed to formulate plans for a machine shop section to be submitted to the council and reported at an adjourned meeting at the time of the spring meeting of the Society.—Editor.)

Mr. Charles H. Logue. After reading Mr. Flanders' paper, it would be useless for me to enter a discussion as to the need of a universally accepted standard for gear teeth, especially for large gears. It is now common practice for all users and makers of large

gears, to correct the teeth for interference, either by shortening the addendum or increasing the angle of obliquity as compared with the 14½ deg. system, or both. This procedure, of course, entails additional expense in manufacture, as special cutters and formers must be made for each gear. Again, each manufacturer, and in many cases the individual user has his own ideas as to how this correction for interference should be made, and also as to the amount.

2 I wish to express my approval of the purpose of Mr. Flanders' paper, namely: the appointment of a special committee of the Society to recommend an interchangeable gear-tooth standard, and also of the action at the last meeting of the Society whereby a recommendation was made to the Council that such a committee be appointed. The present situation is little short of chaotic, and the present "so-called" standard was most aptly characterized by Mr. Wilfred Lewis as "no standard at all." The work before this committee is mountainous, for this problem is probably more complex than any other individual problem in machine design and construction that could be presented. The difficulty of the problem is also a measure of the benefit that will come to the machine-building industry if a standard is recommended and brought into general use.

3 It is apparent that there will be a great saving in the adoption of a rational, universal system, as well as an improvement in tooth-action, the extent of which is entirely unappreciated by gear users. Only a comparatively small part of the gear-tooth surface is in actual use, and the rest of this surface is a detriment rather than a help to the tooth-action. In addition to this detriment, the correction as sometimes made produces surfaces that give an irregular impulse, or series of impulses, to the driven gear by the driver. Thus the teeth of the driven gear have instantaneous accelerations and retardations and lack a regular motion. This, of course, tends to destroy the gears rapidly. I believe that this condition prevails to a greater or less extent, in all involute gears as ordinarily made.

PROPOSED SHORT TOOTH STANDARD

4 In order to set before the Society information as to existing gear-tooth systems, I propose to describe a short-toothed, 20-deg. standard that I began to use some three years ago. Since that time I have advocated this system for all gears heavier than one-diametral pitch, and in many cases for gears of finer pitches. I now see no reason why this system is not universally adaptable. It follows closely the Fellows system as worked out for fine pitches, except that

the addendum bears a definite relation to the circular pitch. This relation is expressed by the equation,

$$addendum = 0.25 \; circular \; pitch$$

5 This quantity was derived from experience and from a study of the tooth parts of the Fellows system. In the Fellows system the addendum varies from 0.264 of the circular pitch to 0.226 of the circular pitch. These factors for the common combination pitches are shown in the following tabulation:

For 2/2½	pitch,	addendum—	0.255	of circular	pitch.
" 2½/3	"	"	0.264	"	"
" 3/4	"	"	0.240	"	"
" 4/5	"	"	0.255	"	"
" 5/7	"	"	0.228	"	"
" 7/9	"	"	0.247	"	"
" 9/10	"	"	0.254	"	"
" 10/12	"	"	0.264	"	"
" 12/14	"	"	0.226	"	"
" 14/18	"	"	0.250	"	"

6 The factor 0.25 is, therefore, a rough mean of the factors shown in the table, and is also a convenient quantity to use in computing gear-tooth parts. This latter advantage is especially true as the thickness of the teeth at the pitch-line, added to the pitch diameter, gives the outside diameter, and this relationship is of convenience when measuring gears in which the pitch-diameter and pitch are unknown. In many cases the only dimensions received by the gear manufacturer are the outside diameter and number of teeth. While this feature should not be an influence in determining the length of addendum to be used, it is a convenient point to keep in mind. For diametral-pitch the addendum is found by dividing 0.7854 by the pitch. This is a well-known factor; is equal to $\frac{\pi}{4}$; is in general use in many engineering formulas, and is easily memorized.

7 The tooth parts for circular pitch are:

Addendum	0.25 ×	cir.	pitch,	instead of	0.3183
Dedundum	0.30 "	"	"	"	0.3683
Working depth	0.50 "	"	"	"	0.6366
Whole depth	0.55 "	"	"	"	0.6866
Clearance	0.05 "	"	"	same as now used	

8 The tooth parts of diametral pitch are:

Addendum	$\frac{0.7854}{P}$	instead of	$\frac{1}{P}$
Dedundum	$\frac{0.9424}{P}$	"	$\frac{1.57}{P}$
Working depth	$\frac{1.5708}{P}$	"	$\frac{2}{P}$
Whole depth	$\frac{1.7278}{P}$	"	$\frac{2.157}{P}$
Clearance	$\frac{0.157}{P}$	same as now used.	

9 In addition to the length of the addendum the other important element of the gear-tooth, to be determined, is the obliquity. While the increase in journal-friction with the pressure-angle is not as great as is generally supposed, yet this angle should be kept as small as is consistent for the purpose intended; that is, to obtain an interchangeable involute system without correcting the tooth-outlines. In the system which I am describing 20 deg. is the angle of obliquity. Thus the two essential elements of the system are, the addendum equal to 0.25 of the circular pitch and the pressure-angle of 20 deg. These correspond very closely with Case 4, as set forth in Par. 44 and 45 of Mr. Flanders' paper. He characterizes Case 4 as a system having an angle of obliquity of 20 deg. and an addendum height equal to $\frac{0.8}{P}$. For circular pitch the addendum would equal 0.8 or 0.2513 of the circular pitch. That is, Case 4 is essentially the system which I am describing.

10 Referring to Par. 45 of Mr. Flanders' paper, from his tabulation captioned, Comparison of Selected Examples of Involute Gear Tooth Systems, I have transcribed the factors:

Smallest pinion in series, to avoid interference	14
Maximum number of teeth without correction for interference with 12-tooth gear	36
Maximum and minimum number of teeth in continuous contact	$\begin{cases} 1.38 \\ 1.18 \end{cases}$
Proportion of side pressure on bearing to tangential pressure	1.064
Strength-factor of rack	0.543
Strength-factor of 12-tooth gear	0.354
Comparative loss of work from friction	552
Comparative durability	1.44

11 He states that the smallest pinion in the series that can be used and avoid interference is one with 14 teeth. The lowest theoretical number of teeth for such a pinion engaging a rack is 13.4. I believe, however, that 13 teeth can be used without correction as the error is less than $\frac{1}{2}$ a tooth, therefore in order to use a 12-toothed pinion, which is today considered a *desideratum*, the only correction necessary is for this pinion alone. In some practice, street railway use in particular, 14 is the smallest number of teeth which is ever used; 12 and 13 are always avoided.

12 In order to use an uncorrected 12-tooth pinion in this instance, without changing the addendum, it would be necessary to increase the angle according to Mr. Flanders' formula, to 21 deg. 13 min. If it is necessary to include the 12-tooth pinion in the interchangeable system, I would prefer to see the angle increased for the reason which I have indicated above. However, I would strongly recommend for consideration an angle of 20 deg. and the addendum as given, and thus consider a 12 and perhaps a 13-toothed pinion as special. These would then be in the same situation as are 10 and 11-toothed pinions today.

13 It will be argued that the short-tooth standard permits of a smaller number of teeth in contact. While this may be true, in some cases, the superiority of this contact has been demonstrated by Mr. Flanders. However, it should be noted that, owing to the increased strength of the tooth that has been shortened and has a wider angle of obliquity, the pitch may be reduced accordingly to give the same number of teeth, or more, in contact, as are in contact in similar gears having the usual length of addendum and a pressure angle of $14\frac{1}{2}$ deg.

14 As a matter of interest it must be pointed out that this system is now in use for the gears of the subway trains in New York, and to the best of my knowledge it is superior in service to the standard-toothed gears that have been discarded. The special 20-deg. involute stub-tooth system described by Mr. Litchfield in his paper on Spur-Gearing on Heavy Railway Motor Equipment, is the same as this short-tooth 20-deg. standard that I have proposed for consideration.

Mr. E. R. Fellows. The conclusions arrived at by the author, as given in table accompanying Par. 45, do not entirely coincide with the writer's experience. The reason is that the form of $14\frac{1}{2}$-deg. tooth considered is virtually a short tooth of this angle, and has theoretically, in these deductions, some of the advantages of the stub-tooth.

The forms selected by the author for the standard or $14\frac{1}{2}$-deg. tooth are those which he infers are produced by a set of formed milling-cutters designed to cut an interchangeable set of gears. As, however, the exact form of these cutters is more or less of a trade secret, he has evidently been obliged to make his own deductions upon some points, such as the exact modification for interference and the angle of the flank below the base line. A little variation in these points makes a considerable difference in theoretical efficiency.

2 The stub-tooth so-called, which is a short tooth of 20-deg., being very little modified for interference, conforms very closely to the theoretical. The standard forms selected give n, the number of teeth in contact, as 0.98. It has been the general experience that gears having a line of action as short as this do not run satisfactorily; they are noisy. And this is the test by which gearing is approved or condemned; a difference of one or two per cent in efficiency being of no importance whatever. An examination of any satisfactory set of gearing of standard form will show that most of the gears bear nearly if not quite to the point. This means that the value of n is ordinarily 1.5 to 1.75, and while the running qualities are satisfactory the efficiency is lower than if the value of n were 0.98.

3 This being the case, it is safe to assume that either the form of standard cutters ordinarily used is not the one discussed by the author, or that gearing, after running a short time, changes from wear sufficiently to give a longer line of action. The author evidently had this condition in mind, as his formula for strength assumes that the stress is applied at the extreme point of the teeth, notwithstanding the fact that according to his first deductions, this would be impossible. We will consider the changes necessary to give to n the value of general practice.

4 In case of two 12-tooth pinions shown in Fig. 2 and 3, the author assumes that interference begins as soon as the theoretical action ends. This is not the case. The path traced by the point D, Fig. 3, beyond the so-called interference point, is an epitrochoid, which so nearly conforms to the theoretical involute, that if the flank of the tooth below the base line be undercut $2\frac{1}{2}$ deg., D will rub the entire distance *ab* of the point of the meeting tooth. The radial flank causes what little interference there may be.

5 The design of cutters for an interchangeable set is a matter of compromise. Strength demands as broad a flank as is possible for the pinion; efficiency demands a short line of action; quiet running requires a longer one. The latter being the point by which the user

tests his gears, it is safe to say that it receives the most consideration. A little compromise would obviate even the undercutting of the flank.

6 Theoretically, in the interchangeable set two pinions of 12 teeth should mesh together. Practice does not demand this, such a case being extremely rare. This combination would give a very low efficiency. If this is imperative, as in the case of spur gear differential of the automobile, gears of greater angle are almost invariably used. It is safe to say that the meshing of two 15 or 16-tooth pinions would fulfill all practical requirements, and anyone who has rolled two standard pinions of 12 teeth together, in the condition which they leave the cutter, will decide that in practice all gears are not absolutely interchangeable.

7 The writer's experience has been largely with generated gears, but from this experience, he would say, that the best practice in gearing of the standard form demands a length of action giving about $n = 1.5$, and that this requirement is met. This value of n would materially change most of the diagrams given, particularly Fig. 12, comparing the lost work, and Fig. 13, comparing durability. If the modification for interference of the standard 12-tooth pinion, instead of being 0.4 of the addendum, be 0.0, and if this modification up to about 30 teeth be a very immaterial amount, the friction or lost work of the average train of gears will be considerably more than that given by the author.

8 In this connection the term "corrected for interference," used by the author and by other authorities on gearing, is open to criticism. As the involute curve is theoretically correct, and after "correction" is only *correct* in the sense that it will mesh with another form which is not in itself theoretically correct, the term "modified" more nearly describes the case.

9 The writer would emphasize the statement in Par. 37 regarding durability. The fact that wear, in the case of the stub-tooth, is distributed over a much greater surface, is a strong point in its favor. This is more marked in the case of the pinion, where most of the wear usually takes place. The result is, that the form of the worn-out stub-tooth is practically that of an involute curve.

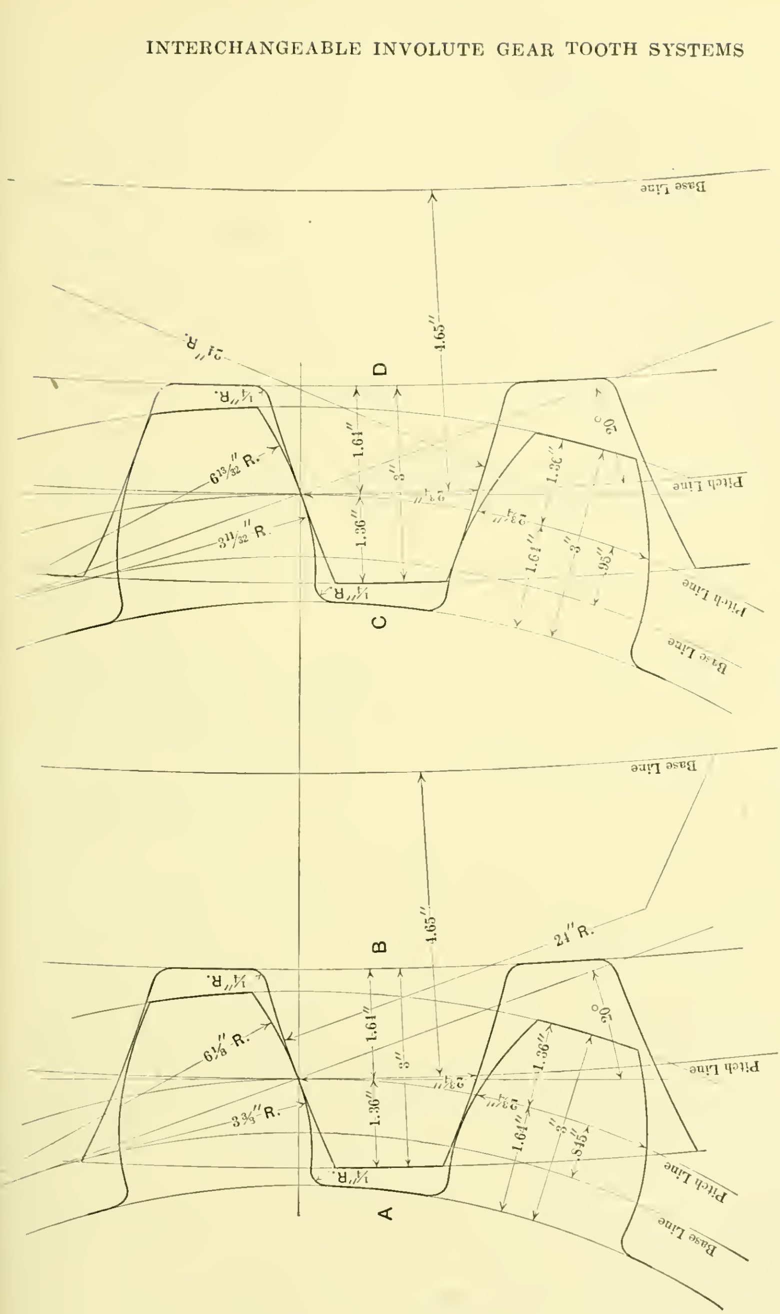
10 The "handicap" of "one form of generating process" is not as serious as might be inferred from Par. 39. As the modification for interference is very simply taken care of by the design of the cutter, it is possible to vary this modification automatically, and to give the teeth of each diameter of gear just the required amount and no more.

11 One important point not touched by the author, is the effect

of what may be termed "shop efficiency" upon the comparative running qualities of the standard and the stub-tooth systems. A shop efficiency of 100 per cent is possible only under laboratory conditions. 90 per cent represents what is probably first-class commercial conditions, and 70 per cent is more common. The running qualities of both types of gears would probably be very nearly the same under laboratory conditions, but under practical ones the balance is in favor of the stub tooth and increasingly so as the shop efficiency decreases.

Mr. Tho. Fawcus. We find the Brown and Sharpe system sufficient in every respect up to 1 P. For large gears we generally use the 20-deg. involute, with a depth of 0.55 of the circular pitch, or about 0.8 S. A layout for some $5\frac{1}{2}$ in. pitch gears recently made is shown in Fig. 1.

2 The gear manufacturer is usually in the unfortunate position of having to assume responsibility for gears designed by others for work of which he is not informed. If the gears fail, it is blamed on the only detail left to his discretion; namely, the kind of iron or steel or other material used. A recent case where material was blamed for being "too soft," upon investigation showed gears put to a service calling for nearly four times the strength by Lewis' formula. For these reasons I think the question of durability has not received sufficient attention. Tooth forms do not trouble gear manufacturers much; it is easy to make conjugate involute teeth, and, for heavy gears at least, the short tooth is preferable. But we need to know more about the durability of certain combinations of metals at high and low speeds. This is most important in gears under heavy load and at low speed where the material must be such as will not crush on the line of contact; also in worm gearing, which is in a class by itself with regard to the materials of which it should be made. The usual practice of making the worms of steel and the wheels of cast-iron is very bad. But if the gear-maker offers any objection, he is confronted with the fact that the combination has proved satisfactory in some particular case. That results are most varied and even contradictory is true; one pair of worm gears succeeding where a perfectly similar pair will fail. This is sometimes partly explained by excessive friction caused by tight bearings in new machines, or shaft centers too close together, or insufficient lubrication. The cutting action once started is difficult to stop and usually results in the destruction of the wheel.



SPECIAL 20-DEG. TEETH

Pinion A, 16 Teeth; Pitch, 5½-in.; Face, 18-in.; Pitch-Diameter, 28-in.; Radius Base Circle, 13.155. in.
Gear B, 88 Teeth; Pitch, 5½-in.; Face, 18-in.; Pitch-Diameter, 154-in.; Radius Base Circle, 72.35 in.
Pinion C, 18 Teeth; Pitch, 5½-in.; Face, 18-in.; Pitch-Diameter, 31½-in.; Radius Base Circle, 14.8 in.
Gear D, 88 Teeth; Pitch, 5½-in.; Face, 18-in.; Pitch-Diameter, 154-in.; Radius Base Circle, 72.35 in.

3 This is, I know, departing somewhat from the subject under discussion, but I mention it because it is a very real difficulty with which engineers and manufacturers have to contend.

Prof. F. DeR. Furman. At the end of Par. 12 the author states: "In Fig. 7, it will be seen, a similar increase of addendum makes no change in the number of teeth in contact, as the action is still limited by points C and D." In Par. 15 it is stated: "When $\alpha = 20$ deg. and $S = 1.0$, the amount of contact between any two gears of the same series from 12 teeth to a rack is constant at about 1.4" and also "that if in any series there is interference in the case of two pinions having the smallest number of teeth allowed by the series, the amount of action obtained in that case is constant for any other case throughout the whole series, up to that of two racks meshing with each other. As far as the author knows, this condition has never before been noticed." Also in Par. 15 we find: "The $14\frac{1}{2}$-deg. standard series of whatever height of addendum gives less than continuous action, being about 0.987."

2 All the above statements must rest on the assumption that there is no contact between the tooth surfaces beyond the interference line, in which case there is a fair portion at the end of the tooth that could be cut off without interfering in any way with the running. If a set of interchangeable wheels were made with conjugate extensions beyond the interference line none of the statements quoted would hold. Since the extension cannot be involute, and must be of some other form, that form might as well be the simplest one, which is the epicycloidal. And further if we give the epicycloidal form to a fair portion of the face, and flank, and leave only a portion of the tooth near the pitch circle, of involute form, we may as well abandon the involute system entirely for interchangeable gearing, and adopt the epicycloidal system instead for interchangeable work.[1] Then in the endeavor to perfect gearing we could at least work towards theoretical conditions, instead of using the approximate methods referred to in Par. 32 for forming the extensions to the involute beyond the interference line. These extensions I understand are not in practice true conjugate curves and therefore must allow, theoretically at least, the follower to slow up while the driver

[1] To meet the difficulty involved in cutting epicycloidal teeth at the pitch circle, we could adopt a combination outline for interchangeable teeth in which the tooth form is involute for a short distance on either side of the pitch line and epicycloidal for the remainder of the face and the flank.

continues at its uniform velocity, the result being a blow as the teeth come into contact.

3 The author shows that in a system having an angle of 22½ deg. or more, and where $S = 0.8$, there is no interference, and it follows that the teeth may be correctly made of the involute form all the way to their tips. But even here smoothness of action will not be obtained so long as the teeth are cut with standard rotary cutters in which each one must cut a certain range of wheels. Take for example the No. 3 cutter cutting 35 to 54 teeth, it would follow that the cutter must be formed to suit the involute of the smallest wheel and therefore would cut away too much of the face of all wheels having 36 to 54 teeth. This means that there will be correct driving contact only at or near the line of centers, and as the driving pair pass through receding action the follower slows up, thus allowing the next tooth of the uniformly moving driver to come into violent action with impact and noise, instead of easy contact with the follower tooth.

4 In Par. 24, the author states that "In order to get the proper form of fillet on the 12-tooth pinion, the rack tooth was lengthened by an amount equal to the clearance, and the corner of the extended tooth was rounded with a radius equal to ⅔ of the clearance." I would like to ask why the author goes to the trouble of lengthening the tooth and then rounding it off instead of simply finding the curve traced by the corner of the rack tooth on the revolving plane of the pinion and then placing the fillet curve within the one thus found?

5 From the present paper it would seem that there would always be difficulty, if not impossibility, in producing a series of smooth-running interchangeable gear wheels, all the way from a 12-tooth pinion to a rack on the involute system. If a series of intermediate sized changeable involute wheels were desired the problem would appear to be an easier one.

6 The most difficult part of the problem for interchangeable involute wheels lies in the fact that the face or addendum must be the same throughout the series. It is quite different, however, for an independent pair of wheels which are always to run together. Here the addenda may be made unequal to great advantage, thereby avoiding in most cases the trouble due to interference, and giving a receding action greater than the approaching by any desired amount. This involves the making of a special cutter for each wheel, but where a large number of wheels are to be duplicated the extra expense for cutters would be more than offset by the smoothness due to correc theoretical action.

7 An example of the use of teeth having unequal addenda will be given in a discussion of Mr. Litchfield's paper to be presented this morning. In that illustration it will be shown that a very strong tooth may be obtained with a $14\frac{1}{2}$-deg. pressure angle because: (1) the necessary amount of action may be obtained with this angle by a relatively short tooth; (2) a specially-formed large fillet may be placed at the root.

8 From the above, and from deductions from Mr. Flanders' paper, it would appear that if we give to high-class gearing the special consideration which each case deserves, theory is pointing to the use of a small pressure-angle for two wheels that are to run always together, and to a large angle for a series of interchangeable wheels, if the involute system is used.

Mr. A. L. DeLeeuw. The main point which has been made perfectly clear to me is that there is some difference of opinion on this subject, which is of some significance as showing that many of us have reached a point where we are striving for something different, supposing it to be better.

2 The motion by Mr. Lewis is to the effect that the council be requested to appoint a committee to consider a standard system of gearing. I am inclined to think this motion should be broadened by making it read "standard systems" instead of "a standard system." Not necessarily that we wish more than one system, but that it would leave the committee which investigates the matter free to consider it from all possible angles. I will therefore second the motion of Mr. Lewis and ask him kindly to assent to my suggestion to broaden the terminology slightly so as to include any kind of system or systems which may be proposed.

Mr. Lewis accepted this suggestion, with the proviso that the resolution should be confined to involute interchangeable gearing; and also a suggestion by Mr. E. H. Neff that it be put in the form of a recommendation to the Council that they take action upon its provisions. The motion which is expressed by the following, was then put and unanimously carried.

2 Resolved: That the Council be asked to appoint a committee to investigate the subject of interchangeable involute gearing and recommend a standard, or standards, if found desirable.

The Author. Referring to Par. 2 of Mr. Burlingame's discussion. it should be noted that I did *not* base my data on a form of tooth

which is a true involute for its whole length. In fact, a main point of the investigation was to show how little of the outline (about one-third) could, in the standard form, be involute. This is one of the grounds for criticism of the present form of tooth, which thus relinquishes, to a great extent, the advantage which the involute curve gives, of perfect action at varying center-distances. Besides the small length of theoretical curve possible makes the form of tooth indeterminate, except by empirical methods. I followed an old suggestion in making the indeterminate portions of cycloidal form; this was done only in order to obtain a reasonable working-basis from which to start the investigation, and was made necessary by the lack of definite information from the proprietors of the present system. I apologize for calling this hypothetical system the "Brown & Sharpe" system. This was an inadvertence; proper correction will be made before the paper is published in a permanent form.

2 In Par. 3, Mr. Burlingame objects to basing the calculations for the number of teeth in contact, etc., on the small amount of theoretical action possible with this hypothetical tooth form. (And this in spite of his previous assertion that the calculations were based on a tooth of true involute form for their whole length.) This procedure is justifiable, since, in a partially involute form of tooth, only the involute portion remains in action if the center-distances (as must be expected to happen in practice) are slightly greater than called for theoretically.

3 It is true, as intimated by Mr. Burlingame in Par. 7, that the smaller the pressure angle, the smaller the backlash when the gears are slightly separated. This should have been included as one of the advantages of the present system for such uses as change-gears, printing-press work, etc.

4 I do not wish to be put in the position of discounting the complexity of the problem of interchangeable gearing. This question is indeed one of some difficulty. I do feel, however, that a new solution may be safely sought, through the ability and experience at the command of this Society. The fact that the Brown & Sharpe standard gives excellent results for a wide field of work, even when the whole range from 12 teeth to the rack is covered by a set of 8, or at the most, 15 cutters, would indicate that the refinements hinted at are more imaginary than real; and the fact that two very different systems of interchangeable gearing (those mentioned by Messrs. Lewis and Hunt) have been tried out by exacting and competent engineers over a long period of years and over a wide range of applica-

tion, to the entire satisfaction of the users, would indicate that departures from the old form can be made without fear of disastrous results. Furthermore, there is no practical engineering problem which cannot be solved by the combined application of technical training, perseverance, and common sense.

5 Mr. Fellows (Par. 1) makes the criticism that a longer theoretical action would have been obtained if the 12-tooth pinion had been considered as having the involute extend out to the points of the teeth, and if the flanks of the mating teeth and been undercut, when necessary, to allow this. It is true that more action might be obtained by a system so designed; this action would be truly involute in large gears, but in the case of small pinions it would amount, practically, to a rocking of the face of the tooth about the base of the involute on the mating tooth. This action is purely fortuitous, and is not susceptible of analysis. Besides, it undercuts the flanks of small pinions, leaving a distinct shoulder at the base line. This shoulder does not appear in teeth shaped by standard-formed cutters, where the involute merges smoothly into what appears (on the 12-tooth pinion) to be practically a radial flank. Thus no escape is left from the conclusion that teeth shaped by standard-formed cutters depart at their points very materially from the true involute form. On the other hand, if my memory serves me, a 12-tooth pinion generated by Mr. Fellows' process shows a distinct shoulder at the base circle, so it is very likely that the involute in that case extends nearly or quite to the points of the teeth.

6 Professor Furman calls attention to the fact that the cycloidal system avoids all the corrections and modifications necessary with the involute system; and he suggests that its claims be considered in place of the involute for use in a standard system. It is true that the cycloidal form shows a marked advantage from the standpoint of pure kinematics; but, as Mr. F. J. Miller has pointed out, natural evolution, in free competition with the involute form, has resulted in the practical elimination of the cycloidal system. One of the disadvantages of the latter is the difficulty of obtaining sufficient side clearance for formed cutters; another is the difficulty of generating the curves as compared with the involute. For a general purpose system of interchangeable gears, the cycloidal form is "out of the running."

7 Professor Furman, in Par. 2, asks why I used the method described for generating the flanks and fillets of the teeth used in finding the strength-factors. The most convenient way to study a

standard system theoretically is to consider it as generated from a standard rack. This has its counterpart in actual practice in the action of the gear-hobbing machine. To obtain, then, a rationally practical form of tooth, it was considered to be generated from a hob. In making a hob, I would round the corners as described, to obviate a rough or stepped generation of the fillet; this procedure also makes the fillet as large as it can be, and still be safe from interference with a sharp-cornered rack tooth.

8 His suggestion in Par. 6 that much better results can be obtained by departing from the regulation proportions, is true. I have given much study to this matter. Many cases are found where the added expense of special cutters is warranted. This use of special gearing is becoming more common than many designers realize, especially in such work as printing-presses, metal-planers, etc., where the best possible results are required. I wish to make the suggestion that all such special gearing be stamped with some recognized symbol to show that it is special. This would avoid costly errors later, when the inevitable repairs have to be made, since it is often impossible to tell by inspection, or by any ordinary means of measurement, whether or not a gear is of standard form. All this is aside from the question at issue, however.

9 Mr. Logue's discussion expresses the viewpoint of the engineer who has specialized in the design and manufacture of gearing, and very logically and forcibly describes present conditions in the field of heavy work. These conditions now appear to be well on the road to remedy, thanks to the action of the members and the Council of this Society.

THE SLIPPING POINT OF ROLLED BOILER TUBE JOINTS

By Profs. O. P. Hood and G. L. Christensen, Published in The Journal for Mid-October

ABSTRACT OF PAPER

The object of this paper is to supply data regarding the behavior of joints made by the familiar process of rolling boiler tubes into containing holes. Attention is called to the fact that the stress at which the tube slips is as important as the ultimate strength of the joint. The results of experiments on tube holes of various forms and with various degrees of rolling are shown by plotted curves, and a simple method is indicated whereby the slipping point of the usual joint may be raised so high as to bring the full elastic strength of the tube into use.

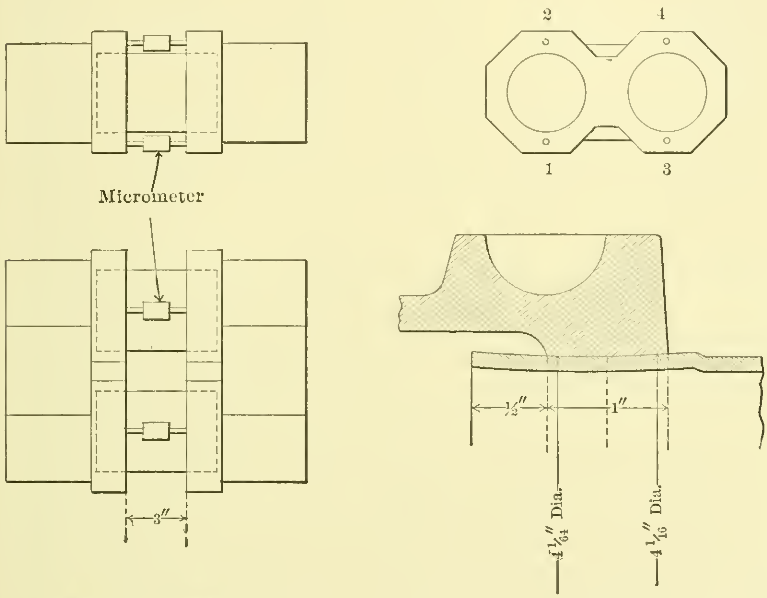
DISCUSSION

Mr. J. C. Parker. Professors Hood and Christensen have shown a new phase of the subject of expanded joints. The straight non-beaded joint with about ½ in. seat has come into extensive use in water-tube boiler practice. These tests make it evident that there is considerable movement with joints of this character, especially in boilers where the tubes are not free to expand independently, and the shorter the joint the greater will be the leakage.

2 Boiler insurance companies have lately been demanding that the tube ends project ½ in. past the seat and be flared about ⅛ in. Comparing tests No. 2 and No. 4 the flaring does not appear to have strengthened the joint in any way. This agrees with our tests, which did not show a noticeable increase in holding power from flaring over the ordinary straight rolled joint which has a slight flare from the taper mandrel. Some projection past the seat, however, is essential, and ½ in. appears to be about right.

3 When Professor Hood drew our attention to this subject we made a number of tests of 4-in. tube joints with water pressure.

Pairs of boxes were connected by two nipples 6 in. long and the slip measured by a micrometer between the backs of the boxes set in center punch marks. The accompanying table gives the results of one of the tests. The micrometer was set up in the centers so it would not spin freely and by holding it lightly between the fingers a less slip could be detected than could be measured. In no case did the micrometer indicate any spring or stretch or any movement whatever until the slipping point was reached, when a little jump would occur each time and all the measurements would be found to be increased.



METHOD OF MEASURING SLIP IN TESTS UPON BOILER TUBE JOINTS

4 The slip invariably began around a pressure of 1150 lb. per sq. in. and further slip occurred generally with each 100 lb. added to the pressure. A pinhole in a handhole cover developed at a pressure of 2100 lb. per sq. in. and was calked. At 2660 lb. one of the tube joints began to leak.

5 Short joints are likely to leak from slipping, but a tube well rolled in a long joint acts like a tight-fitting piston which can slip without leaking. The joint shown has proven in practice to have ample holding power and rarely shows any leakage with ordinary rolling.

TESTS OF 4-IN. ROLLED BOILER TUBE JOINTS

Slipping Point. Pressure, Pounds per square inch.	Slip in Inches				
	No. 1	No. 2	No. 3	No. 4	Average
1150	.0017	.0011	.0012	.0002	.00105
1270	.0045	.0008	.0090	.0062	.0051
1510	.0029	.0035	.0003	.0001	.0017
1650	.0024	.0023	.0008	.0012	.0017
1760	.0013	.0005	.0010	.0004	.0008
1870	.0005	.0005	.0006	.0005	.0005
1950	.0031	.0037	.0004	.0014	.00215
2060	.0006	.0012	.0016	.0010	.0011
2150	.0024	.0012	.0036	.0034	.00265
2220	.0008	.0010	.0007	.0007	.0008
2340	.0017	.0017	.0008	.0010	.0013
2450	.0023	.0024	.0011	.0012	.00175
2525	.0022	.0022	.0009	.0012	.0016
2660	.0004	.0015	.0045	.0068	.0033
	.0268	.0236	.0265	.0253	.0255

Prof. C. H. Benjamin. Professors Hood and Christensen are to be congratulated on the success of their experiments in a comparatively new field. Their work seems to offer the first reliable data on the holding power of expanded boiler tubes, a subject on which there has always been considerable discussion and speculation.

2 The use of this method of fastening tubes in modern sectional boilers, where the integrity of the boiler depends upon the holding power of the tube, has rendered the question of even more importance than formerly. In the water-tube boiler of the Babcock & Wilcox type, where the front headers connect with the steam drums above and the rear ones with the mud drum below, the safety of the structure depends entirely upon the permanence of the union between an expanded tube and the header or drum.

3 It seems to me there are one or two points brought out in these experiments which are particularly interesting. First, the slight slipping of the joint at a comparatively low pressure and the fact that this slipping is not particularly affected by increased rolling or by flaring the ends of the tubes. Although it may be desirable to raise this slipping point somewhat, as a matter of economy, it is undoubtedly safer to have it stay where it is. Since slipping will usually be evidenced by leakage, we have here a warning of failure at a comparatively good factor of safety. If the slipping pressure is brought too near the breaking pressure, the first evidence of weakness might be complete rupture of the joint.

4 Second, that flaring does not seem to have the important effect as a safeguard which has sometimes been claimed. There has been considerable argument in the past, especially between boiler makers and insurance companies, as to the necessity or advisability of flaring. It is evident from the diagrams, as in Fig. 1, that initial slipping will not be prevented by flaring to any extent and, as in the case of Curves 2 and 4, the flaring would have but little effect on the ultimate strength. All of the diagrams and figures would seem to show that medium or hard rolling has more effect in raising the ultimate strength of the joint than any flaring of the tube. I have always believed this to be the case, because rolling produces the friction between shell and tube to prevent initial slipping and it also produces a shoulder or abutment outside the shell which comes into play a little later (See Fig. 1). The flaring, on the other hand, does not come into play until there has been considerable slipping of the tube. The claims made by some authorities that flaring increases the strength 300 per cent are evidently erroneous. The difference is probably due to better rolling.

5 The margin of safety in expanded tube joints can be illustrated by considering a 4 in. boiler tube of 10 gauge, expanded in a plate of $\frac{5}{8}$ in. thick. The net area of the tube will be 1.627 sq. in. and if we call its tensile strength 60,000 lb. per sq. in. the ultimate strength of the tube in tension will be 97,620 lb. Allowing for friction between tube and shell 750 lb. per sq. in., it would require about 5900 lb. to slip the joint and from 8000 to 12,000 lb. to pull it out. With a pressure of 150 lb. per sq. in. inside the shell, the pressure tending to push out the tube would be 1884 lb. We thus have a factor of safety of over 3 as regards initial slipping and as regards ultimate failure, a factor of safety of from 4 to 6. A comparison of these figures, however, with those representing the strength of the tube, will show that we are very far from having 100 per cent joint.

6 The facts brought out with regard to the serrating of the surfaces are very interesting. I think this should be done with care since it is better to have the point where leakage will show considerably below the ultimate strength of the joint.

Mr. E. D. Meier. I think the tests including even the least result show that there is ample security against danger from slipping of the tubes. The authors have shown by their careful experiments that the opinion prevalent among boiler manufacturers that it is not necessary to flare the tubes if you roll them in tight, and further, that it is not necessary to use excessive rolling, is well grounded.

2 A simpler method than that suggested for preventing leaky tubes is to keep oil out of the boiler. I have never known a case of leakage around tubes that had been well rolled and properly set that could not be traced to oil. If in rolling in the tubes there is the slightest film of oil left on the tube or sheet there will be the same trouble.

Mr. M. W. Sewall. I have been interested in comparing the slipping point referred to in the paper and the leakage point as shown in the tests on tubes, made by The Babcock & Wilcox Company.

2 The tests referred to were made by subjecting the tubes to hydrostatic pressure after they had been expanded into properly prepared flanges, having ½ in. wide seats. The fluid pressures at the leakage points are given below, whereas the tables in the paper give the force tending to drive the tubes out of their seats. With very light and improper expanding on 3¼ in. tubes, leakage occurred in one case at 300 lb. pressure, in another at 500 lb. per sq. in. Reduced to the stress tending to force the tubes out of their seats this becomes 2490 and 4150 lb. respectively.

3 When expanded properly the leakage points for 3¼ in. tubes were 800 to 1450 lb. per sq. in. These become when reduced to the stress tending to force the tubes out of their seats 6640 and 12,035 lb. respectively. The end pressures at the leaking point are somewhat comparable with those shown by the curves in Fig. 2 of the paper. It will be noticed, however, that the values obtained with the light and improper expanding, namely 2490 and 4150, are somewhat higher than those showing the slipping point in the curves. A, B and C. The figures for the end pressure in the cases of properly expanded tubes, which show 6640 and 12,035 lb. respectively, are higher than the initial slipping point shown in curves 22 and 19. In fact, there is no case in Fig. 1 to Fig. 5 showing an initial slip as high as 12,000 lb. There are four curves, three in Fig. 2 and one in Fig. 3, showing slips of 0.01 in. with a stress higher than 12,000 lb.; all the others are considerably lower.

4 I would like to ask whether, where a decided thickening of the tubes is shown in the tube sheet in the engravings of the paper, there was an error in making the cuts. Apparently not, because it is repeated several times. I would like to know how the thickening is accomplished if the illustrations correctly represent the conditions.

The Authors. In order that comparisons can be made with tests upon other tubes it is necessary to note that the radial pressure and

therefore the friction which can be developed by the rolling process varies directly with the thickness and inversely as the diameter of the tube.

2 Also a tube of larger diameter and the same normal pressure, having a greater circumference and bearing area, would offer a greater resistance to slip in proportion to the increase in diameter.

3 Also that if the force be applied as an internal fluid pressure this is added to the normal pressure produced by rolling and should increase the holding power.

4 Mr. Sewall's direct experiments on the leakage point as distinguished from the slipping point are of great interest and value, and it is hoped that the complete experiments may be made available to all. The figures which he has given should be modified to make them comparable with the three inch tube tests.

5 The $3\frac{1}{4}$ inch tubes used by the Babcock & Wilcox Co., are presumably standard 11 gage tubes which are 10 per cent thicker than the 12 gage 3-inch tubes. The tube diameter is also $8\frac{1}{3}$ per cent greater; therefore the normal pressure probably developed in the $3\frac{1}{4}$-inch tube when rolled would be 110 per cent ÷ 108.3 per cent = 101.5 per cent of that in a 3-inch tube. The area of the seat would also be $8\frac{1}{3}$ per cent more than in the 3-inch tube so that we should expect 101.5 × 108.3 = 110 per cent more resistance to slipping if the stress were applied in the same way.

6 With the stress applied as an internal fluid pressure of 300 to 500 lb. per square inch and assuming a coefficient of friction of 0.3 then 450 to 750 lb. of the resistance found in the B & W tests with light rolling was due to the internal test pressure and the remaining 2040 to 4400 lb. was 110 per cent of what would be expected with the thinner and smaller 3-inch tubes.

7 This makes the comparable figures 1855 to 4000 lb. and quite within the range of the curves shown in Fig. 2. It would appear that had the slip of these tubes been measured it would have been found that leakage occurred with a slip of less than 1/100 of an inch, for the resistance of the 3-inch tube at 1/100 in. slip was 6000 lb. Referring to the properly expanded tubes cited by Mr. Sewall it appears that 1200 to 2175 lb. of the resistance was probably due to the friction caused by the internal fluid test pressure and of the remaining 5440 to 9860 lb., 4950 to 8960 lb. is what could be expected from a 3-inch twelve gage tube.

8 This again brings the comparable figures well within the range between curves B & C in Fig. 2. Probably the harder rolled tubes

leaked before a slip of 2/100 occurred. It seems evident that direct comparison of figures should not be made from tests of 3-inch twelve gage tubes under a direct push and from tests of $3\frac{1}{4}$ inch eleven gage tubes under hydraulic pressure.

9 With proper corrections however, the two sets of experiments seem to agree very well. In Fig. 8 and Fig. 9 the cut showing the form of joint is diagrammatic only and purposely distorted to aid the eye in finding the several tests. The proper dimensions are all given so that the true form of the joint is disclosed, but had the drawing been to scale the detail would have been too small to be distinctive. There was no thickening of the tube walls.

10 The test figures given by Mr. Parker when plotted give a load-slip curve of the same character as those shown in Fig. 10, and the values at the slipping point when corrected for thickness, diameter and fluid pressure are comparable with the values found for the same form of joint in test No. 1, 2 and 4. It appears that leakage actually occurred with a slip of about 0.025 in. even with a seat one inch wide and a smooth hole. In fact this test and a reasonable inference from the B & W tests seem to show that leakage does occur with a very small disturbance of the original seating of the tube although the hole may be a smooth machined one.

11 Professor Benjamin raises a very pertinent question as to whether it is not better to have the point of weakness localized at the tube ends where leakage will give so timely a warning. While the factor of safety of the ordinary joint is ample for usual cases yet, as pointed out in the paper, there are stresses due to temperature problems not readily computed and which in some cases make a stronger joint desirable.

THE TOTAL HEAT OF SATURATED STEAM

By Dr. Harvey N. Davis, Published in The Journal for November

ABSTRACT OF PAPER

It has for some time been suspected that Regnault's formula for the total heat of saturated steam,

$$H = 1091.7 + 0.305\ (t - 32)\ \text{B.t.u.}$$

is considerably in error. This conclusion is confirmed by computing H above 212 deg., in terms of H_{212}, from the throttling experiments of Grindley, Griessmann and Peake, and the direct specific heat determinations of Knoblauch and Jakob. The result is

$$H = H_{212} + 0.3745\ (t - 212) - 0.000550\ (t - 212)^2$$

The best value of H_{212} seems to be 1150.3 B.t.u. The range of the new formula is from 212 deg. to about 400 deg. The greatest error in Regnault's formula in this range is 6 B.t.u. at 275 deg., but if extrapolated to higher temperatures the error in it increases very rapidly.

Below 212 deg. the observations of Dieterici, Smith, Griffiths, Henning and Joly show a thoroughly satisfactory agreement among themselves, and prove that Regnault's formula runs high, the error reaching 18 B.t.u. at 32 deg. There are corresponding errors on the specific volume values ordinarily used.

DISCUSSION

Prof. C. H. Peabody. This paper is so complete and conclusive that it needs no discussion; rather it is to be accepted as the most valuable contribution to the science and practice of steam engineering since the determination of the mechanical equivalent of heat by Rowland.

2 To my mind this piece of work, which cannot be appreciated too highly, emphasizes two features, first, that no good scientific work is ever wasted, and second, that the highest scientific ability is required to interpret and apply experimental data. It would add to the value of the paper if the author would append the references to the authorities quoted, somewhat more fully than he has done.

3 In consequence of the information presented by Dr. Davis it will be necessary to recompute our steam tables; in fact his paper informs us that a new table is to be published, which I am sure will be welcomed by engineers.

4 It may, however, be pointed out that existing tables are in error only to the extent of half of one per cent for the middle range of temperatures, and that such errors will give engineers but little concern, however distasteful they are to the computers of such tables.

5 But our temperature-entropy diagram and the temperature-entropy tables (for which I am responsible) need change in only one feature and that the one of least importance.

6 To show that this is true let us consider the usual expression for entropy of wet steam,

$$\frac{xr}{T} + \theta$$

x = quality or dryness factor.
r = heat of vaporization.
T = absolute temperature.
θ = entropy of the liquid.

7 In computations for a temperature-entropy diagram or table we begin by assigning some desired value to the entropy which remains constant for a given abscissa or column. Then

$$\frac{xr}{T} + \theta = \phi$$

$$\therefore\ xr = (\phi - \theta)\, T$$

which determines the product xr for any temperature and entropy even though the factors x and r should be unknown. Consequently the heat contents

$$xr + q = (\phi - \theta)\, T + q$$

will not be affected by changes in r.

8 Again the usual manner of computing the specific volume of saturated steam is by the equation

$$s = \frac{r}{A\,T}\,\frac{1}{\frac{dp}{dt}} + \sigma = n + \sigma$$

s = specific volume of saturated steam.
A = reciprocal of Joules equivalent.
$\frac{dp}{dt}$ = slope of temperature-pressure curve.
σ = specific volume of water.
u = increase of volume due to vaporization.

9 Now the specific volume of wet steam is

$$v = xu + \sigma = \frac{xr}{AT} \frac{1}{\frac{dp}{dt}} + \sigma$$

or substituting for xr its value

$$v = \frac{(\phi - \theta)\ T}{AT} \frac{1}{\frac{dp}{dt}} + \sigma$$

$$\therefore\ v = \frac{\phi - \theta}{A} \frac{1}{\frac{dp}{dt}} + \sigma$$

which shows that the specific volume for a given temperature and entropy will not be changed by a change in r.

10 On the contrary the quality or dryness factor

$$x = (\phi - \theta) \frac{T}{r}$$

depends directly on r.

11 These equations are deduced to show that of the several properties given on a temperature-entropy diagram or table only one, namely the quality, needs revision. The fact that the initial value of this factor is seldom known to the degree of certainty represented by half of one per cent has no particular bearing on this discussion unless it makes engineers somewhat impatient concerning it.

Prof. William D. Ennis. Professor Peabody has said what was fitting, and what he could most appropriately say, regarding this masterly paper. When the aims and methods of pure science can be as helpfully presented to engineers as Dr. Davis has presented them, we must derive inspiration. Two questions immediately arise in reviewing these revised values for the total heat of steam. First, are they of considerable engineering importance? Second, are the new

values final? On the first point: Even if we take H_{212} at 1150.3 the difference between the new and old values within ordinary ranges is small. Take, for example, an engine test showing a thermal efficiency of 0.1500, using saturated steam at 150 lb. pressure. The old and the new values of H are respectively 1191.9 and 1193.4; a difference which would make the thermal efficiency, based on the new value, read 0.1498. At the same time, the new values differ from the old to such an extent as to promise some noticeable variations in our steam tables.

2 As to the finality of Dr. Davis' deductions, it seems unquestioned that throttling methods for the determination of H are better than the older method, *provided* the values of C_p are accurately known and there is no question as to the relation between p and t at saturation. But are the values of C_p as yet established? Professor Heck has harmonized the two best sets of experiments and has regarded the question as "about settled." Dr. Davis also regards the question as settled, but in a different way; while Professor Thomas evidently holds it to be unsettled, because he is still experimenting. We cannot get final values of H until we have final values of C_p.

3 I am not quite clear as to whether the apparent check on Knoblauch's values of C_p is not after all in large measure an example of the circular fallacy. The analytical expression for C_p includes three terms. The first of these, $\frac{dH}{dt}$, may be taken from Regnault's formula or from the new formula; the value in the latter case depends quite directly upon C_p. The second term of the expression for C_p, $\frac{r}{T}$, also depends directly upon C_p, for $r = H - h$ and H has been computed from C_p. For the same reason, the third and last term also depends upon C_p, although the derivative $\left(\frac{dv}{dt}\right)_p$ may be obtained without regard to Knoblauch's values for C_p. The computed values of C_p thus depend, though not simply, upon the values assumed for C_p in the first place. We could, of course, obtain a great variety of curves like that suggested by the small circles in Fig. 6, according to the origin of our values of H and $\left(\frac{dv}{dt}\right)_p$. I have found, for example, using Regnault's values for H, p, t and Wood's formula of relation between p, v and t for the derivative, at 140 lb. absolute pressure, that $C_p = 0.622$; a value rather closer to Knoblauch's than Dr. Davis' computation would give. This strikes one as being purely accidental.

4 With correct values of C_p, there seems to be no possible objection to the accuracy of re-computing H by the proposed method. The best check on the whole work would be, then, to finally determine H directly by some appropriate method.

Prof. Robert C. H. Heck. I have not been able to give this subject the amount of consideration which it ought to have, as a preliminary to close quantitative criticism; but several points have occurred to me as worthy of general remark.

2 Dr. Davis, having made a close study of the data along this line, is highly competent to express an opinion as to how nearly the data which he has used are to be accepted as final. We may well accept his conclusion that further changes in the determined values of the specific heat of superheated steam will not produce any great changes in his total heat. Here the word "great" is used from the view-point of scientific precision, not in the engineering sense; and from this point of view the errors in Regnault's formula are very great. But whether the range of probable error, or of uncertainty, is as narrow as Dr. Davis thinks, is to my mind rather doubtful.

3 One fact that has been brought out in all the more useful experiments, especially those of Knoblauch and Jakob, is the extreme difficulty of actual physical realization of that state of steam, so simple in idea, known as dry saturation. This shows up very clearly when Regnault's values are plotted for comparison (Fig. 3 of the paper); consistently, his results fall below the others, indicating the probability, which has frequently been remarked, that his steam was not really dry.

4 Knoblauch and Jakob put their steam through a preliminary superheater, of the form of a long vertical cylinder, with a succession of "pine-tree" radiators, made of glass tubes on metal frames, and with the electrical conductor coiled on the glass tubes; current could be passed through as many as desired of these radiators, and the rest left dead; and the temperature of the current of steam could be measured at the dividing plane between each pair of radiators. It was found that the steam rose in temperature in passing the successive active heaters, but in the dead range it at first dropped off a little and then settled to uniformity from point to point along the line of flow. The drop after leaving the region of heat-impartation shows that sensible heat was being taken up in the steam-current, as by evaporation; and was explained as indicating the presence of

moisture or of saturated steam in the body of quite highly superheated steam, until sufficient time, with thorough mechanical mixture, had produced homogeneity.

5 In the experiments of Professor Thomas, the steam was passed through a number of small holes (in effect, tubes), where heat was imparted to it by electrical heater-coils. In one experiment the steam was just brought to the point where any more heat would make the temperature begin to rise above that of saturation; in the next, the steam was heated to some higher point; and the difference in energy consumed was the heat for superheating from saturation. Aside from any question as to accuracy in observation and in measuring instruments, it is legitimate to be doubtful, first, whether the steam is homogeneously dry saturated in Experiment A; second, whether it is homogeneously superheated in Experiment B.

6 In the throttling calorimeter, the steam at first flows through the orifice in practically adiabatic expansion, some of it being condensed in the operation; then, as the jet comes to rest in the low-pressure chamber, the kinetic energy gained in that first operation is changed back to heat, and the body of steam is thereby superheated.

7 Now the important question is, may we safely assume that the steam in the low-pressure section of the throttling calorimeter is homogeneous when its temperature is measured? The best case for the defense is made when a porous plug is used instead of an orifice, as in the experiments of Griessmann. In general, though, the probabilities appear to be more against the throttling method than against that of Thomas. Under the excellent work which Dr. Davis has done lies this uncertainty as to the inherent reliability of his data.

8 I turn now to the question of the specific heat of superheated steam near the saturation limit—assuming that this limit exists as a sharply defined line, and can be experimentally realized. In the paper which I presented at the Detroit meeting, an attempt was made to combine the results of the best experiments to date. The most uncertain thing about the operation of superheating was the starting point; but I had to have something to start from, and so what seemed the best and most intelligent guess was made. It was, to a considerable degree, however, just a guess, although with the redeeming feature that the resulting uncertainty was much less than the probable error in the total heat up to saturation. In the condition of the data, the best that could be aimed at was essential correctness for engineering purposes, with a judicious balancing of

indications and probabilities. The present paper steps upon a higher plane; and with its results fully confirmed, we shall be ready to go out into the region of superheat and really "get things down fine."

9 There is one idea to which I must again take exception, and this is the assumption that the initial specific heat of superheated steam under constant pressure must rise to infinity at the so-called critical temperature, 689 deg. fahr. Infinite specific heat is the characteristic of the ordinary mixture of steam and water, because such a mixture can absorb heat at constant pressure without rise of temperature. This property disappears, however, at the beginning of the critical state; and when it has disappeared from its proper habitat, to import it into the foreign region across the boundary appears to be rather unjustifiable.

10 One point further is to be noted, which even yet is, however, of little more than theoretical interest. The total heat which remains constant in a throttling operation is not quite the same as that which was measured by Regnault in his calorimeter and which is given in our steam tables. In the throttling calorimeter, what we may call the work of the feed-pump is included in the total heat. This total heat, which remains constant in the ideal case of no-radiation, comprises not only the internal or intrinsic energy, but also the external energy of expansion under constant pressure, measured by the product of pressure by volume. In Regnault's experiments, steam was generated in a little boiler, and passed at once into a calorimeter, where it was condensed and cooled, the whole operation taking place under full pressure: then the heat gotten out of the steam and measured was, in intent, just what is put into the steam in the ordinary boiler, but did not include the work done by the feed-pump in forcing the water into the boiler. Until our experimental data are much more reliable than any now available, this small difference remains of theoretical rather than practical importance: but it enters into every precise expression for the energy of the steam-jet, and must be taken into account in calculations.

Prof. Lionel S. Marks. For a long time it has been evident that Regnault's values for the total heat of saturated steam required some revision. Particularly is this true for steam of low pressure. Forty years ago Herwig[1] pointed out that the values of the total

[1] Herwig Pogg. Ann. Vol. 137, 19, 592. 1869.

heat below 120 deg. fahr. were all too low. In his low pressure experiments, Regnault's method of measuring the temperature of the evaporating water by the vapor pressure in the condenser, has very properly given rise to criticism. At higher temperatures the break in the experimental results is clear evidence of the existence of some notable error.

2 But it is not only on the score of inaccuracies in his determinations that Regnault's work has been subjected to adverse criticism. Many of the students of his work who have accepted as correct his experimental results, have found themselves unable to accept his interpretation of his results by a straight line law connecting total heats and temperatures. If the observations above 178 deg. cent. are set aside (on account of the trouble with the apparatus at that temperature) it will be seen from Fig. 3 that his points do not lie on a straight line—that they lie on a curve which resembles closely the Davis curve. Several physicists in recent years have found that a second degree equation gives the best representation of the relation of total heats and temperatures found by Regnault.

Thus Wüllner[1] proposes

$$\lambda = 589 \quad + \ .6003\, t - \ .001246\, t^2$$

Ekholm[2] gives

$$\lambda = 596.75 + 0.4401\, t - 0.000634\, t^2$$

and Starkweather[3] finds from Regnault's observations

$$\lambda = 603.2 \ + .356\, t \quad - .00021\, t^2$$

for temperatures above 100 deg. cent., and

$$\lambda = 598.9 \ + .442\, t \quad - .00064\, t^2$$

for temperatures below 100 deg. cent. (These equations are for 15 deg. calories and centigrade degrees.)

3 In his investigations of other liquids Regnault gave second degree equations for the relation between total heat and temperature in almost every case. It was the results of his trouble with his apparatus at 178 deg. cent. that forced him to give a straight line relation between the total heat and temperature of saturated steam. It will be seen that the Davis equation representing the relation

[1] Wüllner Lehrbuch der Experimentalphysik. Vol. 2, 773. 1896.

[2] Ekholm, Fortschritte der Physik. Vol. 46 II, p. 371.

[3] Starkweather, Am. Jour. of Science (4) Vol. 7, p. 13. 1899

between the total heat of steam and its temperature between 212 deg. and 400 deg. fahr. and based upon the work of a number of modern investigations is of the same form as those given by the most recent analysis of Regnault's work.

4 Other equations have been proposed in recent years based entirely or partly upon other investigations than those of Regnault. Dieterici[1] has deduced an equation for r based on his own experimental value of 0 deg. cent. on Regnault's work, and on certain theoretical and empirical conclusions. The equation is,

$$r = 5948 - 0.559t - 0.000{,}002{,}234t^2$$

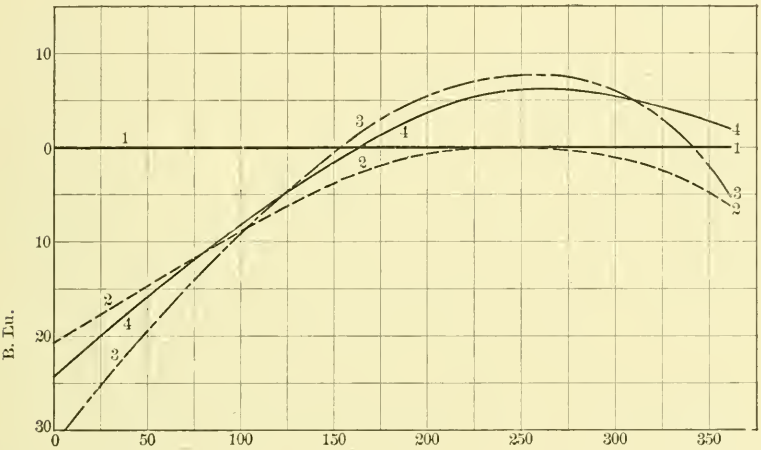


FIG. 1 VARIATION FOR REGNAULT'S VALUES OF r CURVE 1–1, REGNAULT; 2–2, THIESEN; 3–3, LINDE; 4–4, DAVIS.

and it shows the same kind of deviation from Regnault's straight line law as the other cited equations. One of the most prominent is that of Thiesen[2] which gives an expression for the value of the latent heat of vaporization of any liquid in terms of the critical temperature, T_{c1},

$$r = k\,(T_c - T)^{\frac{1}{3}}$$

for water,

$$\log_{10} k = 1.924, \text{ and } T_c = 638 \text{ deg. cent.}$$

[1] Dieterici, Z.V.D.I., 49 (1905), p. 362–7.

[2] Thiesen, Verh. des Phys. Ges. zu Berlin, 1897–8.

Besides this Linde[1] has deduced the values of the latent heat of vapori zation from the specific volume determinations of Knoblauch, Linde and Klebe by the Clapeyron equation

$$r = A\,T.\frac{dp}{dt}\,.\,u$$

The relation between the values of r, as found by Regnault, by Thiesen, by Linde and by Davis are shown in Fig. 1. (Below 212 deg. fahr. the Linde curve is continued through the experimental points of Griffiths and Dieterici.) It will be seen that the Thiesen, Linde and Davis curves show deviations from Regnault's values which have the same general characteristics.

5 Above 400 deg. fahr. there are no reliable experimental observations. If the Davis formula were assumed to be true for temperatures above 400 deg. fahr. it would lead to a maximum value of the total heat at 552 deg. fahr. The critical temperature is 689 deg. fahr. There is no direct experimental evidence to show that the total heat goes through such a maximum and deductions from characteristic equations cannot be used, as they, of necessity, must be widely extrapolated to give any evidence in that region. The value of the total heat must however reach a maximum before the critical temperature.

6 It can be shown that at the critical temperature $\frac{dH}{dT}$ is negative. The isothermal for the critical temperature is generally assumed to be horizontal (on the pv plane) where it meets and is tangent to the steam dome. If that is so, the value of $\frac{dH}{dT}$ is minus infinity at the critical temperature. If the critical isothermal is not tangent to the steam dome where it meets it, it must be because the steam dome is not rounded on top but comes to a peak at the intersection of the water and saturated steam lines. In this case the value of $\frac{dH}{dT}$ at the critical temperature will be finite but still negative. In either case the value of $\frac{dH}{dT}$ is negative and must have gone through zero in approaching the critical temperature, or in other words the total heat, H, must have gone through a maximum. Just where that maximum value occurs, there is no direct evidence to show either for water or for any other liquid. It is probable that the maximum

[1] Linde. Mitt. über Forschungsarbeiten, 1905, No. 21, p. 71

value does not occur as far from the critical temperature as an extrapolation of the Davis formula would indicate, though there is no experimental evidence to support this opinion.

7 The method that has been used in this paper for finding the variation of the total heat of saturated steam with the temperature is a method capable of giving very accurate results. The remarkable agreement of the results from the three separate sets of throttling experiments is valuable evidence on that point. The accuracy depends, however, on the use of the proper values for the specific heat of superheated steam. As Dr. Davis has pointed out there is very

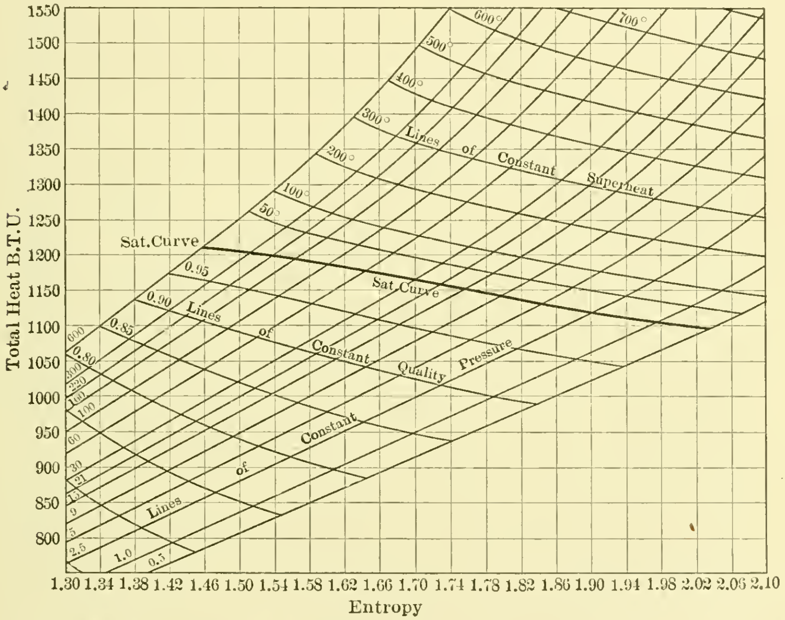


FIG. 2 MOLLIER DIAGRAM SHOWING TOTAL HEAT AND ENTROPY OF STEAM, BASED ON TOTAL HEAT VALUES OF DR. DAVIS

little question as to the correctness of the Knoblauch values of specific heat at low pressures and moderate superheats. For higher pressures and moderate superheat if the Knoblauch values are somewhat high (as the thermodynamically computed values of C_p at the saturation line, Fig. 6, would indicate) the effect will be to make the Davis total heat curve (Fig. 3) somewhat low at high pressures. It will be seen that the Davis curve goes close to the two Regnault (R) circles above 180 deg. cent. It is not known exactly what changes were made by Regnault in his apparatus after it had broken down at 178 deg. cent.,

but it is highly improbable that he succeeded in obtaining dry and saturated steam above that temperature. He certainly had not obtained it at lower temperatures and apparently was at no time cognizant of that fact. If there was no other source of error present the Regnault circles should be below the correct curve, *i.e.*, the Davis curve should lie above the Regnault circles.

8 At the present state of experimental knowledge of the specific heats of superheated steam the Davis curve seems to be the best that can be drawn. Ultimately, it will probably be found that it should

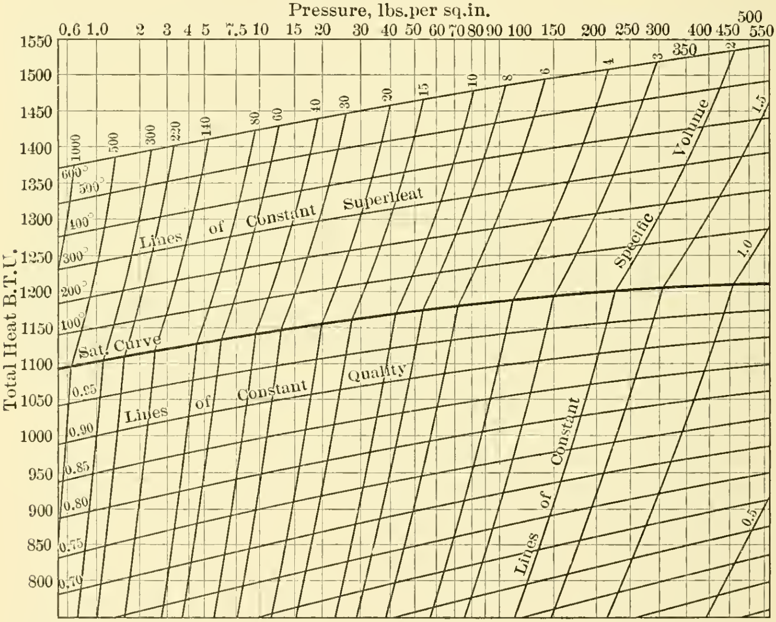


Fig. 3 Total Heat-Pressure Diagram Showing Specific Volumes, Based on Values of Dr. Davis

lie somewhat higher at high pressures and it is probable that an equation giving a maximum value of the total heat at a temperature considerably nearer to the critical temperature will represent the facts better than the equation proposed. I have had the opportunity of going over the work of Dr. Davis in considerable detail and in my opinion the claim he makes for his formula of an accuracy within one-tenth of one per cent between 212 deg. and 400 deg. fahr. is justified.

9 For the purpose of facilitating calculations involving saturated and superheated steam two diagrams (Fig. 2 and 3) have been pre-

pared. These diagrams have been plotted using the total heats of saturated steam given in this paper and the calculated corresponding values of entropy and specific volume. The specific volumes, entropies and total heats of superheated steam have been taken or calculated from the best modern data.

10 Of these two diagrams Fig. 2 is the total heat-entropy diagram devised by Professor Mollier, showing the total heat and entropy of steam in any condition and permitting the immediate determination of the work done in the Rankine unjacketed cycle; of the change in the condition of steam during adiabatic expansion or throttling: and also giving immediate information about wet steam of any usual quality. The other diagram, Fig. 3, is a total heat-pressure diagram showing specific volumes, qualities, and superheats. This diagram is plotted with pressures as abscissæ on a varying scale—equal distances along the axis of abscissae represent equal increments in the temperature of saturated steam corresponding to the indicated pressures. A scale of this kind has the advantage of spreading out the constant specific volume lines at the lower pressures. The second diagram (Fig. 3) is of the greatest value when problems involving volumes or ratios of expansion are to be solved. By the use of the two diagrams singly or together it is possible to solve a large number of commonly occurring problems in steam engine and steam turbine work—some of which problems can otherwise be solved only by a protracted series of trials and errors.

11 There is an apparently curious feature about these diagrams to which attention may be called. The lines of constant superheat are seen to diverge from the saturated steam line at high pressures. This of course results from the large specific heat of moderately superheated steam at high pressures. Such a divergence must necessarily take place. The total heat of saturated steam is tending to a maximum at some temperature below the critical temperature; the total heat of superheated steam along a line of constant superheat (and therefore of increasing pressure and temperature) does not pass through any maximum.

Prof. I. N. Hollis. This, perhaps, is one of the most important subjects that the mechanical engineer has to take up at present. There will not be great changes in Regnault's tables, but the paper points the way to greater scientific accuracy in the work of the mechanical engineer. Up to this time we have had so much work in developing the great projects American engineers have had to under-

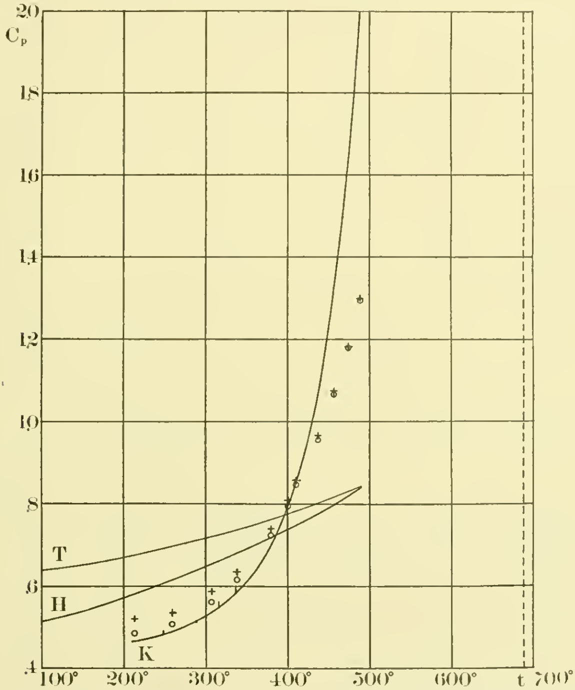
take, that we have paid more attention to the strictly practical side of questions and have permitted the electrical engineers to far surpass us in mathematical work given to the profession. So I welcome this paper by Dr. Davis, who, by the way, is a physicist at Harvard University and not an engineer, as it opens the way for greater accuracy in mechanical engineering matters.

The Author. The friendly words both of approval and of criticism with which this paper has been received are much appreciated by the author. In particular Professor Peabody's intention to recompute his well-known steam tables on the basis of these new values is the pleasantest recognition which they could have. The ease with which this can be done for the wet steam part of his temperature-entropy diagram is most surprising, and it is unfortunate that equally simple laws do not hold for superheated steam. It is hoped that the lack of references which he criticises will be remedied by the accompanying partial bibliography of the subject.

2 The original paper should also have contained a statement as to the heat unit employed. Two such are available, the standard B.t.u., which is the heat required to raise one pound of water from 60 deg. fahr. to 61 deg. fahr., and the mean B.t.u. which is the 180th part of the heat required to raise a pound of water from the freezing point to the boiling-point. Of these, the second is better known in terms of mechanical or electrical units than the first, because the specific heat of water happens to be changing with temperature more rapidly near 60 deg. fahr. than elsewhere, so that the experimental determination of the standard B.t.u. is difficult and uncertain. An additional advantage of the mean B.t.u. is the simple conversion-factor ($\frac{5}{9}$) between steam tables based on it and those based on the Bunsen or mean calorie, now becoming standard abroad. Inasmuch as the difference between the mean B.t.u. and the 60 deg. B.t.u. is probably between one-thirtieth and one-tenth of one per cent, so that it makes practically no difference to the engineer which he uses, the mean B.t.u. has been used in this paper and in the steam tables which are to be based on it.

3 It seems necessary to emphasize again that the point of view of this paper is not so much that the question of the specific heat of steam is "about settled," as that it makes very little difference in the results of this paper whether it is settled or not, because *the computation method is extremely insensitive to errors in* C_p. To prove this, the total heat of saturated steam (H), has been recomputed

using Thomas' values which are at the opposite extreme of the C_p controversy from Knoblauch's. The result is to raise H by an amount which is zero at 212 deg., is well under a quarter of one per cent at 300 deg. and 67 lb. and is only about two-fifths of a per cent at 400 deg. and 250 lb. As was said in the paper, this is not an estimate of the probable error of the H formula given, for Thomas' values at low pressures and close to saturation are generally admitted to be too large. It is simply to show strikingly how small a difference in H is caused by comparatively large changes in C_p.



Reproduction of Fig. 6 of the Author's Paper, with Values Added of C_p from Thomas

4 Finally, the statement that the circularity of the reasoning at the end of the paper is apparent, not real, has been questioned. Let us, therefore, use the values of H, of r and of u obtained as above *from Thomas' values of* C_p as the basis of a recomputation of C_p by the method of Par. 19. The results are plotted with stars in the accompanying figure, which is otherwise a reproduction of Fig. 6 of the paper. The circles in it were obtained in the same way from

data based wholly on Knoblauch's values of C_p. It is evident that no matter what set of values we start from, the method leads in the end to practically the same curve. The fact that this curve is, in general, much more like Knoblauch's than like Thomas' would seem to be conclusive.

BIBLIOGRAPHY

Pressure-temperature measurements.

[1] Henning, Wied. Ann. IV vol. 22 (1907), pp. 609–630.

[1] Holborn and Henning, Wied. Ann. IV vol. 26 (1908), pp. 835–883.

Throttling experiments.

Grindley, Phil. Trans. (London) vol. 194 A (1900), pp. 1–36.

Griessmann, Zeit. V. D. Ing., vol. 47^2 (1903), pp. 1852–1857 and 1880–1884: also Forscharb (Berlin), Heft 13 (1904), pp. 1–57.

Peake, Proc. of the Roy. Soc. (London), Series A, vol. 76 (1905), pp. 185–205.

Total heat measurements.

Regnault, Rel. des Exps., Mems. de l'Acad. des Scies. de l'Inst. de France, vol. 21 (1847), pp. 635–728.

Dieterici, Wied. Ann., vol. 37 (1889), pp. 494–508:

See also Wied. Ann., vol. 16 (1905), pp. 593–620 for a new evaluation of the constant of the calorimeter.

Smith, Phys. Rev., vol. 25 (1907), pp. 145–170.

Griffiths, Phil. Trans. (London), vol. 186 (1895), pp. 261 et seq.

Henning, Wied. Ann., IV vol. 21 (1906), pp. 849–878.

Joly, in an appendix to Griffiths' paper above (p. 322).

Discussions.

Smith, Monthly Weather Review, Oct. 1907.

Dieterici, Zeit. V. D. Ing., vol. 49 (1905), pp. 364–365:

also Wied. Ann., vol. 16 (1905), pp. 908–913.

Starkweather, Am. Jour. of Sci., (4) vol. 7 (1899), pp. 13, et seq.

Thiesen, Verh. der Phys. Ges. zu Berlin, vol. 16 (1897), pp. 80–82.

Linde, Forscharb. (Berlin), Heft 21 (1905).

[1]Of these only the first had been published when the computations for this paper were being made, but the new experimental data in the second paper agree almost perfectly between 212 deg. and 400 deg. with the values which were used.

GAS POWER SECTION

REPORTS AND DISCUSSIONS AT THE ANNUAL MEETING

In the January number of The Journal was published a brief account of the business session of the Gas Power Section, held during the Annual meeting of the Society, with the reports made by committees of the Section. As supplemental to this, there is here given the following report of the Executive Committee of the Section, which outlines a comprehensive plan for committee work; there is also appended discussion presented upon the Report of the Standardization Committee which has formed the subject for discussion at previous meetings as well.

EXECUTIVE COMMITTEE'S PROGRAM

RESOLVED; that the following committees be recommended for appointment

a Nominating Committee.

- (1) Canvass for candidates.
- (2) Place at least two candidates in nomination for each office, including standing officers and Executive Committee.
- (3) Committee to consist of nine men with not more than four in New York City.

b Tellers Committee.

- (1) Three members, all in New York district.

c Library Committee.

- (1) To keep track of bibliography and maintain two lists.
    - *a* Publications in Library.
    - *b* Publications which are not on file in Library.
- (2) Some member of the engineering magazine staff should be placed upon this committee.
- (3) The committee should contain men who can read:
    - *a* French.
    - *b* German
    - *c* Spanish.
    - *d* Italian, and possibly
    - *c* Swedish.
    - *f* Russian.

(4) The Gas Power Section should provide copies of The Journal for the use of the reviewers.

(5) The Committee should make a bi-yearly report giving the lists of material in the library.

(6) The Committee to consist of 15 members, to be made up largely of men in editorial and professional work.

d Committee on Installations.

(1) To list all installations. For this purpose the committee should prepare a standard report form showing completely the equipment, capacities, etc., with dimensions. This committee should keep in touch with the manufacturers.

(2) The Committee to consist of three members.

e Committee on Plant Operation.

(1) Should prepare forms to show load curves, average, maximum, minimum, variations with the time of day, time of year, etc., or descriptions to cover these points in case the load curves cannot be plotted.

(2) Forms should also give the cost, character and amount of materials both in total and per unit, such as fuel, lubricating oil, batteries, current water gaskets, waste, cleaning, etc.

(3) Repair materials and costs.

(4) Operating labor, number and character of men and wages paid (total and per unit).

(5) Repair, labor, cost, etc.

Note: Where these items cannot be divided report in groups or in totals

(6) Detailed dimensions, etc., of the plant.

(7) Data on reliability of operation, that is, long runs.

(8) The Committee should consist largely of operating men.

(9) It is suggested that 20 men serve on this Committee.

f Committee on Accidents, Break-Downs and Failures.

(1) This committee to keep in touch with the liability companies, builders and operators, especially abroad, relating to both American and foreign equipment.

g Committee on Question Box.

(1) To conduct a correspondence on questions and answers and to publish complete lists of all questions and answers, as has been done by the National Electric Light Associations and the Gas Light Associations.

(2) Committee of five.

The Executive Committee would welcome suggestions from the membership regarding members for these various committees.

Affiliates of the Section are eligible to membership on these committees, and their hearty coöperation in the work is deemed extremely important.

Respectfully submitted,

R. H. Fernald
F. H. Stillman
G. T. Rockwood
F. R. Low

Executive Committee.

REPORT OF COMMITTEE ON STANDARDIZATION

DISCUSSION

Prof. Lionel S. Marks. In the discussion of the heat value of a gas the terms "lower" heat value and "effective" heat value have been used as synonymous. It seems to me a pity to introduce into gas engine practice the confusion which must result from this nomenclature. The two words have definite and different meanings in German practice. "Effective" heat value is the heat value of unit volume of a gas under the conditions of pressure and temperature at which the gas is used. The capacity of a gas engine depends on the effective heat value of the gas. At high altitudes a gas of given composition has a lower effective heat value and consequently an engine using it has diminished capacity. Effective heat value as defined above is a useful quantity and no other name has been proposed for that quantity. It is to be hoped that the committee will follow the German practice in the above respect. "Effective" heat values can, of course, be either "higher" or "lower" heat values.

2 There can be but little doubt that "lower" heat values give the better basis from which to measure the relative efficiencies of different gas engines. There is, however, some divergence in practice in the method of computing lower heat values. Many engineers find the lower heat value of a gas by subtracting from the higher heat value (as determined by the Junker calorimeter) the latent heat, at atmosphere pressure, of the steam that is formed by combustion. The British Institution of Civil Engineers in its code of rules finds the lower heat value by subtracting from the higher heat value the total heat of the steam at atmosphere pressure measured above water at 32 deg. fahr. The Verein deutscher Ingenieure takes as the lower heat value the heat which is liberated by the complete combustion of the fuel when the products of combustion are cooled to the original room temperature at constant pressure—it being assumed that all moisture present remains in the form of a vapor.

3 There is only one meaning of lower heat value which is logical. The use of the lower value is based upon the knowledge that at the temperatures existing in gas engine cylinders, the working substance

is a mixture of gases and highly superheated vapors. The fact that water vapor condenses after leaving the cylinder and therefore gives up more heat than would be the case if it remained a vapor, does not help the engine at all. Two exactly similar engines using fuels which differed from one another only in the matter of condensibility after leaving the cylinder ought to show the same efficiency on the lower heat basis. They will do so only if the lower heat value is calculated on the assumption that the water vapor remains a vapor down to the room temperature.

4 If one pound of dry and saturated steam at a temperature t_s is cooled at constant pressure to the room temperature t_r, it gives up $(r_s + q_s - q_r)$ B.t.u. This is the heat given up by the steam if "higher" heat-values are used.

5 If the dry and saturated steam could be kept a dry vapor when cooled at constant pressure to the room temperature it would give up

$$\int_{t_r}^{t_s} C_p \, dt \text{ B.t.u.}$$

This is the heat given up by the steam if "lower" heat-values are used. The difference between the higher and the lower values is consequently

$$w \left(r_s + q_s - q_r - \int^{t_s} C_p \, dt \right) \text{ B.t.u.}$$

where w is the weight of steam in the products of complete combustion of the gas.

6 The values of r_s and q_s cannot be found without considerable trouble as they depend upon the temperature at which the water vapor in the products of combustion becomes saturated. This temperature varies with the excess of air used for combustion. The condensation of water vapor in the Junker calorimeter takes place at all temperatures from the saturation temperature to the temperature of discharge of the gases. Consequently the value of $r_s + q_s$ can be stated approximately only. It is probable that the water vapor never forms as much as 15 per cent by volume of the products of combustion; that is, its partial pressure is not more than 2.2 lb. per sq. in. This corresponds to a saturation temperature of 130 deg.

fahr. Condensation of the water vapor would not begin until the products of combustion (at atmosphere pressure) fell to 130 deg. fahr. At that temperature $q + r = 1116$ B.t.u. If the final temperature of the products is 70 deg. we have for the lowest value $q + r = 11,098$ B.t.u. There cannot be any important error in assuming $q_s + r_s = 1110$ B.t.u. (corresponding to $t_s = 120$ deg. fahr.) for such condensation as occurs in a Junker calorimeter. To find the value of $\int_{t_r}^{t_s} C_p dt$ it will be simplest to assume C_p constant—its value averages about 0.46 under Junker calorimeter conditions. The difference between the higher and the lower heat values is then

$$w\ [r_s + q_s - (t_r - 32) - C_p\ (t_s - t_r)]\ \text{B.t.u.}$$

and if t_r is 60 deg. fahr., this difference becomes

$$w\ (1110 - 28 - 0.46 \times 50)\ \text{B.t.u.}$$
$$= w \times 1060\ \text{B.t.u., approximately.}$$

7 Where great accuracy is required it should not be forgotten that the Junker calorimeter gives the real higher heat value only

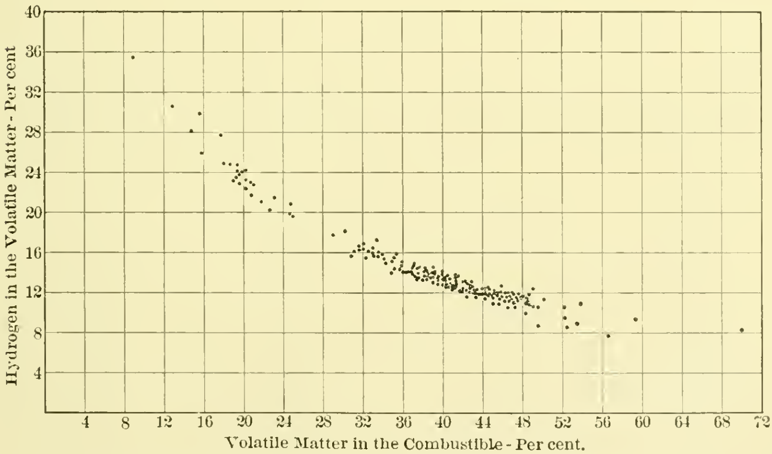


Fig. 1 Results from Analyses of 240 Fuels Made for the U. S. Government

in the case where the air and the gas are saturated with water vapor, where the products of combustion escape at the temperature of the room and where there is no contraction in volume. The importance of the correction for the non-realization of these conditions is shown by the fact that the operation of a Junker calorimeter with producer

gas very often gives no condensation water, that is, that the Junker calorimeter in that case is giving lower heat values. The correction is rather troublesome as it requires the analysis not only of the gas but also of the products of combustion coming from the calorimeter. From these analyses the relative volumes of air, gas, and products of combustion can be determined and if the humidity of the air and gas are also known the weight of uncondensed vapor escaping with the products of combustion can be determined.

8 If the efficiency of a producer is to be determined on a lower heat basis the hydrogen content of the coal must be known. This quantity can be determined experimentally only by carrying out the ultimate analysis of the coal—an analysis which is best made by

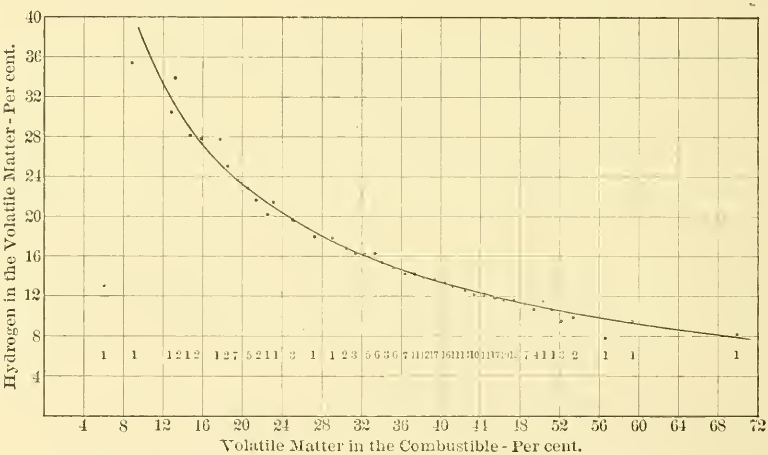


Fig. 2 Curve Plotted from the Diagram in Fig. 1

a chemist. In consequence of certain indications I have made an investigation of an apparent relation between the amount of volatile combustible matter in coal and the hydrogen content. The results of this investigation have just been published elsewhere.[1] They show that for the fuels occurring in the United States it is possible to determine the hydrogen content of the coal from the proximate analysis alone and with an accuracy that is sufficient for all practical purposes. Of 240 fuels analyzed from every part of the United States and of every kind from anthracite to peat, only one fuel (a graphitic anthracite from Rhode Island with six per cent of volatile combustible), shows a hydrogen content differing by more than a negligible amount from that indicated by the proximate analysis.

[1] Power and the Engineer, Dec. 1, 1908.

9 In Fig. 1 are shown points representing the percentage of volatile matter in the combustible and the hydrogen content of that volatile matter for each of the 240 fuels of which analyses have been made and published by the United States government during the past four years. Many of these points are superposed. They represent solid fuels containing from 6 to 70 per cent volatile matter. It will be seen that these points represent a smooth curve very closely To draw the curve accurately the average position of the points has been calculated for each one per cent range of volatile matter and these average points are given in Fig. 2. The number below each point is the number of fuels of which it is the average. Over 90 per cent of the fuels tested have a volatile combustible matter between 8 and 48 per cent. The maximum difference between the curve and the individual points within that range represents a possible error of one-half per cent in the determination of the hydrogen in the coal. Above 48 per cent of volatile matter—that is with lignite and peat—there is possibility of an error of 1 per cent in the determination of the hydrogen of the fuel from the curve. One per cent error in the

TABLE 1

Per cent of volatile matter in the combustible	Per cent of Hydrogen in the combustible	Per cent of volatile matter in the combustible	Per cent of Hydrogen in the combustible
10	3.4	40	5.35
12	3.8	42	5.39
14	4.1	44	5.42
16	4.3	46	5.45
18	4.5	48	5.47
20	4.65	50	5.49
22	4.8	52	5.5
24	4.9	54	5.53
26	4.98	56	5.55
28	5.05	58	5.57
30	5.12	60	5.59
32	5.17	62	5.61
34	5.22	64	5.63
36	5.27	66	5.65
38	5.31	68	5.66
		70	5.67

hydrogen is equivalent to about seven-tenths of one per cent error in the determination of the lower heat value of a fuel. This is the limit of error by the use of the curve, Fig. 2, when lignite or peat is being used. For ordinary bituminous or anthracite coals the limit of error is about three-tenths of one per cent. The probability of error for fuels which are neither extremely high or extremely low in volatile matter is not more than one-tenth of one per cent.

10 In consequence of the above, I believe that engineers may safely omit the troublesome ultimate analysis of coal when they desire to know its hydrogen content and they may determine it from the usual proximate analysis.

11 The accompanying table gives the percentage of hydrogen in the combustible matter corresponding to various percentages of volatile matter in the combustible.

ACCESSIONS TO THE LIBRARY

BOOKS

American Society of Mechanical Engineers. *Transactions.* Vol. 29. *New York, Society, 1908.*

Annual Catalogue of Vassar College, 44th, 1908–09. *Poughkeepsie, A. V. Haight Co., 1908.* Gift.

Association of Electric Lighting Engineers of New England. *Proceedings.* Nantasket Beach, Mass., 1908. Gift of Association of Electric Lighting Engineers of New England.

Commercial Electric Heating. By John Roberts. Gift of C. W. Rice.

Description of a Rotary Engine. By J. E. Harriman. *Boston, 1908.* Gift.

Design of Highway Bridges and the Calculation of Stresses in Bridge Trusses. By M. S. Ketchum. *New York, Engineering News Publishing Co., 1908.* Purchase. $4.00 net.

Disposal of West Side Railroad Tracks. *New York, 1908.* Gift of Merchants' Association of New York.

Domestic Electricity Supply (including Heating and Cooking), as Affected by Tariffs. By W. R. Cooper. *1908.* Gift of C. W. Rice.

Electric Discharge and the Production of Nitric Acid. By William Cramp. Gift of C. W. Rice.

Engineering News. Vols. 1–4, 10. *Chicago, Frost, 1874–1877, New York, Engineering News, 1883.* Gift.

Institution of Naval Architects. *Transactions.* Vol. 15. *London, Sotheran, 1874.* Purchase.

Manchester Steam Users' Association. Memorandum by Chief Engineer, for the year 1907. *Manchester, Taylor, Garnett, Evans & Co., 1908.* Gift.

Manufactures, 1905. Part I, United States by Industries. U. S. Census Bureau. *Washington, Govt., 1907.*

Observations on the Best Means of Propelling Ships. By A. S. Byrne. *New York, C. S. Francis, 1841.* Gift of C. W. Rice.

Preliminary Report on the Mineral Resources of Oklahoma. By C. N. Gould and others. *Norman, 1908.* Oklahoma Geological Survey, Bulletin No. 1. Gift of Survey.

Proceedings of the Session of the American Railway Association, *November 18, 1908. Chicago, 1905.* Association gift.

Report of the Commissioner of Education, 1907. Vol. 2. *Washington, Govt., 1908.* Gift.

EXCHANGES

American Society of Civil Engineers. *Transactions.* Vol. 61. *New York, Society, 1908.*

American Railway and Master Mechanics' Association. *Proceedings of the 41st Annual Convention. Chicago, H. O. Shepard Co., 1908.*

Annual Catalogue of the Worcester Polytechnic Institute, 39th, 1908–1909. *Worcester, Institute, 1908.*

Annual Report of the Chief of the Bureau of Steam Engineering, 1908. *Washington, Govt., 1908.*

Bericht über die Feier des 60-jährigen Bestandes des Osterreichischen Ingenieur und Architekten Vereines am 11 Jänner 1908. *Wien, Vereines, 1908.*

Institution of Civil Engineers. *Minutes of Proceedings.* Vol. 173. *London, Institution, 1908.*

Institution of Engineers and Shipbuilders in Scotland. *Transactions.* Vol. 51. *Glasgow, Institution, 1908.*

Journal of the Canadian Mining Institute, 1908. Vol. 11. *Montreal, Institute, 1908.*

Journal of the Mechanical Engineers' Association of the Witwatersrand. Vol. 1–5. *Johannesburg, 1903–1907.*

List of Members, etc., of the Institution of Engineers, Shipbuilders, etc., as at Oct. 1, 1908. *Glasgow, Elmbark Crescent, 1908.*

CATALOGUES

Corrugated Bar Company, *St. Louis, Mo.* Designing Methods Reinforced Concrete Construction. Vol. 1, No. 6. *1908.*

Electrical Mining Publishing Company, *Chicago.* Electrical Mining, December 1908.

Gem Manufacturing Company, *Pittsburgh, Pa.* Catalogue No. 5.

General Electric Company, *Schenectady, N. Y.* Bulletins No. 4629–31, 4633. Publications No. 3701, 3717, 3725, 5190.

Jeffrey Manufacturing Company, *Columbus, Ohio.* Rubber Belt Conveying Machinery. Catalogue No. 67D.

Keystone Chemical Manufacturing Co., *Philadelphia.* Water Softening and Purification. Proposition Covering the Keystone Pressure Filter System.

Kilbourne & Jacobs Manufacturing Company, *Columbus.* Mine Car Catalogue No. 60.

Wagner Electric Manufacturing Company. *St. Louis, Mo.* Polyphase Motors, Bulletin 82, 1909.

Wheeler Condenser & Engineering Company, *Carteret, N. J.*

Products and Facilities. (Bulletin No. 101.)
Surface Condensers. (Bulletin No. 102.)
Wheeler-Edwards Patent Air Pump. (Bulletin No. 103.)

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

042 High-grade draftsman in the Isthmian service. Two vacancies in the position of general draftsman at an entrance salary of $125 a month. Appointees must have ability to handle estimates, all classes of railroad work, municipal engineering and masonry details.

043 General Foreman of Machine Shops, large electrical concern. Must have had similar position in machine shop or position of authority. Location, Chicago.

044 Master Mechanic in charge of tool equipment and design; expert machinist, good inventive ability and some general experience, preferred rather than special. Location, Chicago.

045 Engineer of Methods, for general investigation work on shop methods, materials, processes, etc. Technically trained man with experience on general investigation work. Man of general ability. Location, Chicago.

046 Head of installation-department for the erecting and installation of motors, generators and switchboards; to look after general repairs and complaints of service; capable of making reliable estimates of costs of work. Location, Chicago.

MEN AVAILABLE

203 Design of boilers, piping and pump layouts, foundations, and all work in connection with power station design. Charge of drafting room. Experienced in construction work, full charge in last position.

204 Member, technical graduate, six years in charge of office of draftsmen, designing automatic and special machinery. Experience as shop superintendent, sales-agent, representative abroad. Inventive ability.

205 Associate Member, technical graduate. Experienced in organizing, systematizing, estimating, inspecting machinery, fuel economy, familiar with modern systems of cost-keeping, capable of handling men and getting results on constructions, operating or in engineering department. Experience for the last eight years has been principally in steel plants.

206 Member, technical graduate, 31 years old, familiar with smelting furnaces, and mill construction desires a position as engineer, or manager of an engineering concern.

207 Mechanical engineer, member, technical graduate, 15 years designing, shop, and selling experience, on hoisting, conveying and transmission machinery, railroad, contractors, and foundry equipment, heavy machine and structural work. Responsible position desired. Good references.

208 Junior, graduate Stevens, would like a position with an engineering firm. Experience in drafting-room and shop.

209 Junior, M. E., graduate of Cornell University, with experience in general construction work and shop management, desires position in the vicinity of New York, in which such experience would be of value.

210 Junior member, aged 28, would like to engage with a consulting industrial engineer, auditor, or mechanical engineer, or take position as assistant to chief executive of a large engineering or industrial concern. Trained as machinist and traveling erecting man. Technical graduate with special work in economics and auditing. Experienced in cost-keeping and purchasing. Has done independent work for several large corporations designing methods to increase net efficiency.

211 Member, graduate of Mass. Inst. Technology, 20 years manufacturing and mechanical experience in textile plants, draftsman, mechanical and steam engineer, master mechanic, assistant superintendent and superintendent. Would prefer a position with some New England mill as mechanical superintendent or as Assistant to manufacturing Superintendent.

212 Junior, 29 years old, now technical editor of a leading engineering periodical, desires to resume active engineering work. Practical experience in power plant design and operation; in hoisting and conveying work.

213 A good machine man desires a position as chief draftsman or superintendent of a machine works, preferably paper machinery.

214 Junior member, four years shop experience in design, and construction of steam engines and general machinery, three years in charge of drafting departments; past five years designing and supervising construction of steam, gas and hydro-electric power plants.

215 Junior member, technical graduate, married, age 35, ten years experience as chief engineer and salesman; design of special machinery and testing work, desires change. Broad experience through travel for special machinery and plant equipments. Will consider equitable proposal from a reliable company as sales manager in branch office, preferably in Southern territory.

216 Wanted, position, preferably with consulting or operating engineers within 100 miles of Philadelphia; Junior Member; M.E., Univ. of Penn.; five years experience in shops and design, inspection and testing of boilers, piping, and power plant apparatus.

217 Member, thoroughly practical mechanic, experienced in operation, erection, design, estimating, and sales; district representative or manager. Specialty, power plant, reciprocating and turbine engines, power transmission appliances

218 Member of the Society, with large experience in executive positions, street railway and electric lighting properties will be pleased to correspond with firms having headquarters in New York. Will invest up to ten thousand dollars.

219 Mechanical and civil engineer, University of Virginia, twenty-three years experience in various branches of engineering, ten years designing and installing hydro-electric power plants. Position desired along similar lines.

220 Member desires to correspond with a concern needing a man thoroughly experienced in the organization and equipment of the up-to-date manufacturing machine shop and foundry.

221 Mechanical engineer, Stevens graduate, ten years experience in shop work and manufacturing operations, plant construction and maintenance, specializing in chemical works. Broad experience in the economic handling of help. Desires position where training would be valuable.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ANDERSON, Robt. Marshall (1898), Cons. Engr., 90 West St., New York, N. Y.

BALLIN, Alfred E. (Associate, 1906), Asst. Ch. Engr., Snow Steam Pump Wks., and *for mail,* 188 W. Utica St., Buffalo, N. Y.

BARNABY, Charles W. (1884), Cons. Engr., 309 Broadway, New York, N. Y.

BEHR, Hans C. (1891), Cons. Mech. Engr., Consolidated Gold Fields of South Africa, Ltd., P. O. Box 1167, Johannesburg, Transvaal, South Africa.

BENNET, Orville G., Jr. (Junior, 1907), care of W. M. Bennett, Bank of Am., 46 Wall St., New York, N. Y.

BENNETT, Geo. L. (1905), 290 Linden Ave., Flatbush, Brooklyn, N. Y.

BRAY, Charles W. (1888), Pres., Am. Sheet and Tin Plate Co., 1325 Frick Bldg., Pittsburg, and *for mail,* R. D. No. 1, Bridgeport, Pa.

BROWN, James Monroe (1900; 1906), De Pere, Wis.

BUCKLEY, Henry W. (1885), Mech. Engr. and Mfr., 141 Broadway, New York, N. Y., and *for mail,* 166 Alden St., Orange, N. J.

BURNS, A. L. (1888; 1897), Secy. and Treas., Jabez Burns & Sons, 600 W. 43d St., New York, and 378 Grand Ave., Brooklyn, N. Y.

CHAMBERLAIN, George E. (1907), Chairman Operating Com. and Ch. Engr., Corn Products Refining Co., 1614 Fisher Bldg., Chicago, and 102 S. Waiola Ave., La Grange, Ill.

CHAMBERLAIN, Harry M. (1907), with J. W. Buzzell, Civil and Mech. Engr., Tribune Bldg., New York, N. Y., and *for mail,* 284 Park Ave., Newark, N. J.

COFFIN, Howard E. (1907), V. P., Chalmers-Detroit Motor Co., and 434 Cadillac Ave., Detroit, Mich.

COLE, George Wm. (Junior, 1907), Secy., The Economic Engrg. Co., 50 Church St., New York, N. Y.

COX, Claude E. (Associate, 1907), Ch. Engr. and Factory Mgr., Interstate Automobile Co., and Delaware Hotel, Muncie, Ind.

DOUD, Arthur T. (Junior, 1907), Cost Engr., J. G. White & Co., 43 Exchange Pl., and *for mail,* 572 W. 187th St., New York, N. Y.

FEICHT, Edward R. (Junior, 1907), M. M., Am. Beet Sugar Co., Lamar, Colo.

GOWIE, William (1905), M. E. and Supt., Scott Iron and Steel Co., Carnegie, and Emily and Warren Aves., Crafton, Pittsburg, Pa.

HALL, Morris A. (1905; Associate, 1906), The Automobile, 231–241 W. 39th St., New York, N. Y., and *for mail,* 332 N. 7th St., Newark, N. J.

HILL, Walter L. (Associate, 1902), Hill-Ray Engrg. Co., 110 State St., Boston, and Arlington, Mass.

HOWE, Albert W. (1903), Hotel St. George, Brooklyn, N. Y.

JONES, David Todd (1898; 1904), Treas. and Genl. Mgr., Wilbraham-Green Blower Co., and *for mail,* 818 High St., Pottstown, Pa.

KWANG, Kwong Yung (1899), Life Member, Dir. and Engr., Lincheng Mines, Lin-Tcheng Sien, Lu-Han Ry., Via Peking, North China.

LANE, J. S. (1882), 50 Church St., New York, N. Y.

LOCKETT, Kenneth (1904; Associate, 1907), Mech. Engr., Orr & Lockett Hardware Co., 71–73 Randolph St., and *for mail*, 5116 Madison Ave., Chicago, Ill., also Pres. and Ch. Engr., Acme Match Co., Roanoke, Va.

McEVOY, Dermot (1906), Revere Rubber Co., Chelsea, and *for mail*, care of Mr. A. V. Sanborn, Prospect Ave., Revere, Mass.

McGREGOR, Alexander Grant (Junior, 1905), Box 1771, Salt Lake City, Utah.

McMULLIN, Frank V. (1903), Supt., Cleveland City Forge and Iron Co., and *for mail*, 10907 Superior Ave., N. E., Cleveland, O.

MERRILL, Geo. H. (Junior, 1898), Secy., Merrill Bros., Maspeth, and 469 Greene Ave., Brooklyn, N. Y.

MOLÉ, Harvey E. (1901), care of R. B. Marchant, 1 W. 30th St., New York, N. Y.

MUELLER, Victor H. (Junior, 1907), Ch. Draftsman, The M. W. Kellogg Co., 117 West Side Ave., Jersey City, and *for mail*, 107 N. 4th St., Newark, N. J.

NEWBURY, George K. (Junior, 1904), Mgr. Plate Dept., Newbury Mchy. Co., and *for mail*, 1222 Gaylord St., Denver, Colo.

PHILP, C. von (1890), Mgr. Mchy. Dept., Bethlehem Steel Co., South Bethlehem, Pa.

RAQUÉ, Philip E. (1891), Cons. Engr., 150 Broadway, New York, N. Y., and 82 Booraem Ave., Jersey City, N. J.

REPATH, Charles H. (1891), Supt. of Constr., Internatl. Smelting and Refining Co., and *for mail*, Box 1771, Salt Lake City, Utah.

RICHARDS, Chas. D. (Junior, 1904), Asst. Engr., Soda-Ash Dept., Solvay Process Co., and *for mail*, 1271 Monroe Ave., Detroit, Mich.

RIDGELY, William Barret (1880; 1895), 1908 Q St., Washington, D. C.

ROBERTS, E. P. (1889), Pres., The Roberts & Abbott Co., 1123 Schofield Bldg., and *for mail* 2095 Cornell Ave., Cleveland, O.

RYERSON, William N. (1906), Genl. Mgr., The Great Northern Power Co., Duluth, Minn.

SCHAEFER, John V. (Junior, 1891), Pres., Schaefer Mfg. Co., Birmingham, Ala.

SCOTT, George Welsby (1903), Cons. Engr., Security Bldg., 5th Ave. and Madison St., and 1594 Kenmore Ave., Chicago, Ill.

SLATER, Alpheus B. (1891), 274 Massachusetts Ave., Providence, R. I.

SMEAD, William H. (Junior, 1906), Mech. Engr., McAdoo Bldg., Greensboro, N. C.

SMITH, Geo. Marshall (Associate, 1904), Julian Kennedy, Pittsburg, Pa.

SMITH, Wm. Edward (1900), Genl. Mgr., Societe Electrique Westinghouse de Russia, and Societe Anonyme Westinghouse, and *for mail*, Strelna, St. Petersburg, Russia.

STANAHAN, O. A. (1900), Engineers Club, 32 W. 40th St., New York, N. Y.

TALCOTT, Robert Barnard (1907), Genl. Mgr., The Vacuum Cleaner Co., 425 Fifth Ave., and *for mail*, 501 W. 121st St., New York, N. Y.

TEELE, Fred W. (1904), Genl. Mgr., Porto Rico Railways Co., Ltd., San Juan, Porto Rico.

THORP, Frederick P. (Junior, 1902), Power and Mining Mchy. Co., 115 Broadway, New York, N. Y.

WALSH, Thomas J. (Junior, 1906), Tampa Elec. Co., Tampa, Fla.
WELLS, Edward C. (1904), Supt., Hardie-Tynes Mfg. Co., and *for mail,* 1618 14th Ave. S., Birmingham, Ala.
WHITTEMORE, John R. (1902), 435 E. Pedregosa St., Santa Barbara, Cal.

NEW MEMBERS

APINE, Sidney B. (1908), Mgr. Mill Power Dept., Genl. Elec. Co., 84 State St. Boston, Mass.
ANDERSON, Frederick Paul (1908), Dir. College of Mech. and Elec. Engrg., Prof. Mech. Engrg., State Univ. of Kentucky, Lexington, Ky.
BACON, Frederick T. H. (1908), Supt. of M. P., Hudson & Manhattan R. R. Co., 30 Church St., and 616 W. 116th St., New York, N. Y.
BARBIERI, Cæsar (1908), Pres. and Mech. Exper., Barbieri & Dellenbarger Co., and *for mail,* 1437 Leland Ave., Chicago, Ill.
BLISS, Edwin C. (1908), Pres., E. C. Bliss Mfg. Co., and V. P., A. H. Bliss Co., also 91 Sabin St., Providence, R. I.
BRUFF, Charles E. (1908), N. Y. Mgr., Power and Mining Mchy Co., 115 Broadway, New York, N. Y.
COLE, Cyrus L. (Junior, 1908), Allis-Chalmers Co., and *for mail,* 3207 Malden St., Chicago, Ill.
DAY, Irvin Wm. (Junior, 1908), First Asst. Engr., Steamship Merida, Ward Line, Pier 14, East River, New York, N. Y.
FREEMAN, J. Porter (1908), Constr. Engr., Alex. Smith & Sons, and *for mail* 225 Woodworth Ave., Yonkers, N. Y.
GRIEPE, August W. H. (1908), Engrg. Dept., N. Y. Edison Co., and *for mail,* 707 Prospect Ave., New York, N. Y.
GROENE, William F. (1908), Ch. Draftsman and Designer, R. K. LeBlond Mch. Co., 4509–4621 Eastern Ave., and 1311 Delta Ave., Cincinnati, O.
HAMILTON, Clinton A. (1908), Genl. Mgr. and V. P., Wisconsin Eng. Co., and *for mail,* 1033 Lake Ave., Racine, Wis.
HANSELL, William H. (1908), Mech. Engr., Standard Roller Bearing Co., and *for mail,* Engineers' Club, 1317 Spruce St., Philadelphia, Pa.
KEAN, A. J. A. (1908), Supt., The Guanajuato Power and Elec. Co., Apartado 23, Zamora, Michoacan, Mexico.
KELLER, Joseph F. (1908), Genl. Mgr. of Wks., Keller Mech. Engrg. Co., 570–576 West Broadway, New York, N. Y.
KELLER, W. H. (Junior, 1908), Supt., Keller Mfg. Co., 21st St. and Allegheny Ave., Philadelphia, Pa.
LEEPER, Ralph W. (Junior, 1908), Experimental Turbine Wk., Genl. Elec. Co., Marysville, O.
McKEE, Robert A. (1908), Engr. Steam Turbine Dept., Allis-Chalmers Co., Milwaukee, Wis.
McKEEN, Wm. R., Jr. (1908), McKeen Motor Car Co., Omaha, Neb.
MACFARLANE, James (1908), Supt. Floating Equip., Isthmian Canal Com., La Boca, Canal Zone, C. A.
MEAD, Daniel W. (1908), Prof. Hyd. and Sanitary Engrg., Univ. of Wisconsin, and *for mail,* 1015 University Ave., Madison, Wis.
MITCHELL, Charles J. (1908), Charge of Design, Fairbanks, Morse Mfg. Co., and *for mail,* 836 College Ave., Beloit, Wis.

MOON, Hartley Allen (Associate, 1908), Ch. Draftsman, Continental Gin Co., Birmingham, Ala.

MURRAY, Arthur F. (Junior, 1908), Mech. Engr., Elliott-Fisher Co., and *for mail,* 1500 S. 12th St., Harrisburg, Pa.

NEILSON, Frederick C. (Associate, 1908), Asst. Inspr. Engrg. Material, Navy Yard, and *for mail,* 64 Kenyon St., Hartford, Conn.

NICHOLS, Charles H. (1908), Cons. Engr., 11 E. 24th St., New York, N. Y.

NORDEN, Carl L. (Junior, 1908), Draftsman, Lidgerwood Mfg. Co., and *for mail,* 395 E. 3d St., Brooklyn, N. Y.

O'NEIL, Frederick W. (1901; 1908), N. Y. Mgr., Nordberg Mfg. Co., Room 1009, 42 Broadway, New York, and 260 Pelham Rd., New Rochelle, N. Y.

PAINE, Sidney B. (1908), Mgr. Mill Power Dept., Genl. Elec. Co., 84 State St., Boston, Mass.

PECK, Henry W. (Associate, 1908), Asst. Elec. Engr., Rochester Ry. and Light Co., 34 Clinton Ave., Rochester, N. Y.

RATTLE, Paul S. (Junior, 1908), Dist. Mgr., The Dayton Hydraulic Mchy. Co., 536 Monadnock Block, Chicago, Ill.

SEAGER, James B. (1908), Genl. Mgr., Olds Gas Power Co., Lansing, Mich.

SHEPERDSON, John Wm. (Associate, 1908), Steam Engr., Cambria Steel Co., and *for mail,* 534 Grove Ave., Johnstown, Pa.

SLAUSON, Harold Whiting (Junior, 1908), Assoc. Technical Press Bureau, 25 W. 42d St., and *for mail,* 513 W. 134th St., New York, N. Y.

SMITH, Harry Ford (1908), Secy. and Genl. Mgr., The Smith Gas Power Co., Lexington, O.

STILLMAN, Edwin A. (Junior, 1908), The Watson-Stillman Co., 50 Church St., New York, N. Y.

SYMONDS, George P. (1908), Ch. of Engrg. Dept., Alberger Condenser Co., 95 Liberty St., New York, N. Y.

TADDIKEN, J. F., Jr. (Junior, 1907), Am. Beet Sugar Co., Grand Island, Neb.

TITCOMB, George E. (1908), Mgr., The J. M. Dodge Co., and 60 W. Tulpehocken St., Philadelphia, Pa.

ULBRICHT, Tomlinson C. (Junior, 1908), Instr. Engrg. Dept., Pratt Inst., and *for mail,* 234 Willoughby Ave., Brooklyn, N. Y.

WHITEHURST, Herbert C. (Junior, 1908), Draftsman and Designer, Evans, Almira'l & Co., 281–3 Water St., New York, N. Y.

WILKINSON, Cecil Tom (Junior, 1908), Elec. Engr., Genl. Elec. Co., and State St., Schenectady, N. Y.

PROMOTIONS

ALFORD, Leon Pratt (1900; 1908), Engrg. Editor, American Machinist, 505 Pearl St. and 67 W. 106th St., New York, N. Y.

ALLEN, Albert Mark (1903; 1908), Cons. Engr., 1130 Schofield Bldg., and 1319 E. 82d St., N. E., Cleveland, O.

CROUCH, Calvin Henry (1898; 1908), Dean, College of Mech. and Elec. Engrg., Univ. of North Dakota, Grand Forks, N. D.

DOUGLAS, Courtney Carlos (1904; Associate 1908), Steam Turbine Engr., Genl. Elec. Co., 84 State St., Boston, and 15 Glengary St., Winchester, Mass.

GORDON, Rea M. (1902; Associate, 1908), Asst. Engr. of Tests, Solvay Process Co., and *for mail,* 533 S. Salina St., Syracuse, N. Y.

KNIGHT, Geo. Laurence (1905; 1908), Designing Engr., Edison Elec. Ill. Co., of Brooklyn, 360 Pearl St., and 1032-A Sterling Pl., Brooklyn, N. Y.

SANGSTER, Andrew (1900; 1908), Supt., Canadian Rand Co., Ltd., and *for mail*, 84 Drummond St., Sherbrooke, Quebec, Canada.

SOPER, Ellis (1905; Associate, 1908), Pres. The Soper Co., 1110-11 Ford Bldg., and 54 Blaine Ave., Detroit, Mich.

YORK, Robert (1901; Associate, 1908), V. P., York-Browning Lumber Co., Memphis, Tenn.

RESIGNATIONS

DEGAIGNE, Oscar V.

RICHARDSON, Harry S.

DEATHS

CORBIN, George W.

HILL, Warren E.

SOULE, Richard H.

WOLFF, Alfred R.

Gas Power Section

CHANGES OF ADDRESS

SAGE, Darrow (Affiliate, 1908), 122 W. 72d St., New York, N. Y.

VERKOUTEREN, A. J. (Affiliate, 1908), Cons. Engr., 600 Springdale Ave., East Orange, N. J.

NEW MEMBERS

BATES, Madison F. (Affiliate, 1908), Stationary Engr., Bates & Edmonds Motor Co., Lansing, Mich.

CHAMBERS, Ralph H. (Affiliate, 1908), Chambers & Hone, Cons. Engr., 15 William St., New York, N. Y.

CRAWLEY, George E. (1908), 557 W. 124th St., New York, N. Y.

DONNELLY, James A. (Affiliate, 1908), Heating Engr., 132 Nassau St., New York, N. Y.

GALLUP, David Lamprey (Affiliate, 1908), Instr. in Mech. Engrg., Worcester Poly. Inst., Worcester, Mass.

GOEBBELS, Leonard V. (Affiliate, 1908), Mech. Engr., N. E. Cor. 33d and Walnut Sts., Philadelphia, Pa.

MacVEAGH, George Day (Affiliate, 1908), Engr. Gas Dept., National Meter Co., and *for mail*, 808 De Kalb Ave., Brooklyn, N. Y.

PETERS, Edward (Affiliate, 1908), 4042 Olive St., St. Louis, Mo.

ULBRICHT, Tomlinson C. (1908), Instr. Engrg. Dept., Pratt Inst., and *for mail*, 234 Willoughby Ave., Brooklyn, N. Y.

Student Branch

STEVENS INSTITUTE ENGINEERING SOCIETY

BACKER, L. H., 1909, 431 W. 6th St., Plainfield, N. J.
BADEAU, R. P., 1909, Stevens Inst., Hoboken, N. J.
BECK, G., Jr., 1909, 100 N. Maple Ave., E. Orange, N. J.
BECKWITH, C. F., 1909, 106 N. Clinton St., East Orange, N. J.
COBB, P. L., 1909, 38 Schermerhorn St., Brooklyn, N. Y.
DRAUDT, O. E., 1909, 38 Cambridge Pl., Brooklyn, N. Y.
EIDMANN, F. L., 1909, 80 Danielson St., Union Hill, N. J.
FORTMAN, E., 1909, 80 Hauxhurst Ave., Weehawken, N. J.
FREYGANG, G. G., 1909, 752 Boulevard Loop, Weehawken, N. J.
HOEXTER, S. J., 1909, 786 Cauldwill Ave., New York, N. Y.
LUDWIG, C. H., 1909, 804 Castle Point Terrace, Hoboken, N. J.
NYLAND, E., 1909, Pres., S. I. E. S., Stevens Inst. of Tech., Hoboken, N J
PEASE, L. M., 1909, 94 Knickerbocker Rd., Englewood, N. J.
PRICE, T., 1909, 65 Newell Ave., Rutherford, N. J.
SIERADZKI, A., 1909, 222 W. 141st St., New York, N. Y.
SIEVERS, E. J. J., 1909, 65 Willow Ave., Hoboken, N. J.
VENNEMA, A. W., 1909, 185 Paulison Ave., Passaic, N. J.
BERGER, J. G., 1910, 18 Carlton Ave., Jersey City, N. J.
CADY, C. I., 1910, Walnut Terrace, Bloomfield, N. J.
CARR, W. DeL., 1910, 15 W. 4th, Bayonne, N. J.
CAWLEY, H., 1910, 91 Broad St., Newark, N. J.
COOK, G. C., 1910, 62 Park Ave., E. Orange, N. J.
CRANE, F. L., 1910, 227 Rahway Ave., Elizabeth, N. J.
CURTIS, J. B., 1910, Stevens Inst., Hoboken, N. J.
CYPHERS, J. F., 1910, 168 Dodd St., East Orange, N. J.
DORER, O. H., 1910, 200 Stuyvesant Ave., Irvington, N. J.
FERGUSON, R. E., 1910, 60 S. Grove St., E. Orange, N. J.
FITZGERALD, C. J., 1910, Stevens Inst., Hoboken, N. J.
GUNKEL, F. H. Jr., 1910, 158 10th St., Hoboken, N. J.
HAYNES, H. H., 1910, 11 W. 94th St., New York, N. Y.
KASSANDER, A. R., 1910, 1350 Madison Ave., New York, N. Y.
MacKAY, C., 1910, 164 Jefferson Ave., Brooklyn, N. Y.
MESSNER, M., 1910, 106 W. 8th St., Bayonne, N. J.
OGDEN, N., 1910, 216 Summit Ave., Summit, N. J.
ROSCOE, A. P., 1910, Stevens Inst., Hoboken, N. J.
WHYTE, A. C., 1910, Ridgefield Park, N. J.

COMING MEETINGS

AËRONAUTIC SOCIETY

February 10, etc., evenings, weekly meetings, Automobile Club of America, W. 54th St., New York. Secy., Wilbur R. Kimball.

AMERICAN GAS POWER SOCIETY

April 27, quarterly meeting, Minneapolis, Minn. Secy., R. P. Gillette.

AMERICAN GEOGRAPHICAL SOCIETY

February 23, 29 W. 39th St., New York, 8 p.m. Acting Secy., Geo. C. Hurlbut, 15 W. 81st St.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

February 12, 33 W. 39th St., New York, 8 p.m. Secy., R. W. Pope.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

February 19, monthly meeting, Toronto Section. Secy. *pro tem.*, W. H. Eisenheis, 1207 Traders' Bank Bldg.

AMERICAN INSTITUTE OF MINING ENGINEERS

February, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY

February 27, Columbia University, New York, February 27, San Francisco Section. General Secy., F. N. Cole, Columbia University,

AMERICAN SOCIETY OF CIVIL ENGINEERS

February 17, March 3, 220 W. 57th St., New York. Secy., C. W. Hunt.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

February 23, March 9, monthly meetings, 29 W. 39th St., New York, 8 p.m. Secy., Calvin W. Rice.

BLUE ROOM ENGINEERING SOCIETY

March 4, 29 West 39th St., New York. Secy., W. D. Sprague.

BOSTON SOCIETY OF CIVIL ENGINEERS

February 17, monthly meeting, Tremont Temple. Paper: Mechanical Refrigeration, H. M. Haven; March 17, annual meeting. Secy., S. E. Tinkham, 60 City Hall.

BROOKLYN ENGINEERS CLUB

February 11. Paper: Control and Management of the Highways of France, N. P. Lewis. Secy., J. Strachan, 197 Montague St.

CANADIAN CEMENT AND CONCRETE ASSOCIATION

March 1–6, Convention, Toronto, Ont. Secy., Alfred E. Uren, 62 Church St.

CANADIAN MINING INSTITUTE

March 3–5, annual meeting, Windsor Hotel, Montreal, Que. Secy., H. Mortimer-Lamb. Windsor Hotel.

CANADIAN RAILWAY CLUB

March 2, Windsor Hotel, Montreal, Que., 8 p.m. Secy., Jas. Powell, St Lambert, Montreal.

CANADIAN SOCIETY OF CIVIL ENGINEERS
February 11, electrical section; February 18, mechanical section; February 25, mining section; March 5, business meeting, 413 Dorchester St. W., Montreal, Que. Secy., Prof. C. H. McLeod.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Manitoba Branch
February 19, March 5, semi-monthly meetings, University of Manitoba. Secy., E. Brydone Jack.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Toronto Branch
February 25, regular meeting, 96 King St. W. Secy., T. C. Irving, Jr.

CAR FOREMEN'S ASSOCIATION OF CHICAGO
March 8. Secy., Aaron Kline, 326 N. 50th St.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
March 9, Cincinnati, Ill.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
March 1, Indianapolis, Ind. Secy., G. B. Staats, Care Penna. Lines.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
March 8, Kansas City, Mo. Secy., F. H. Ashley, Gumbel Bldg.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS
February 11, Toledo, O. Secy., H. M. Ellert.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
February 16, Rossin House, Toronto, Ont. Paper: Y. M. C. A. Work, J. M. Dudley. Secy., C. L. Worth, Room 409, Union Sta.

CLEVELAND ENGINEERING SOCIETY
March 9, monthly meeting, Caxton Building. Secy., Joe C. Beardsley.

COLORADO SCIENTIFIC SOCIETY
March 6, monthy meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

ENGINEERING ASSOCIATION OF THE SOUTH
February 16, monthly meeting, Nashville Section, Carnegie Library Bldg. Section Secy., H. H. Trabue, Berry Blk., Nashville.

ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA
March 2, monthly meeting, Iowa City, Ia. Secy., Dean Wm. G. Raymond.

ENGINEERS' AND ARCHITECTS' CLUB
February 15, 303 Norton Bldg., Louisville, Ky. Secy., Pierce Butler.

ENGINEERS' CLUB OF BALTIMORE
March 6, monthly meeting. Secy., R. K. Compton, City Hall.

ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA
March 2, monthly meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher.

ENGINEERS' CLUB OF CINCINNATI
February 18, 25 E. 8th St. Secy., E. A. Gast, P. O. Box 333.

ENGINEERS' CLUB OF PHILADELPHIA
February 20, March 6, 1317 Spruce St. Secy., H. G. Perring.

ENGINEERS' CLUB OF TORONTO
February 11, etc., weekly meetings, 96 King St. W., Toronto, Ont. Secy., R. B. Wolsey.

ENGINEERS' SOCIETY OF MILWAUKEE
February 10, March 10, 456 Broadway, Milwaukee, Wis. Secy., W. Fay Martin.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

February 15, monthly meeting. Paper: The Manufacture of Portland Cement, W. M. Kinney. Secy., E. K. Hiles.

EXPLORERS' CLUB

March 5, 29 West 39th St., New York. Secy., H. C. Walsh.

ILLUMINATING ENGINEERING SOCIETY

February 11, monthly meeting, New York Section, 29 W. 39th St., 8 p.m. Secy., P. S. Millar.

INTERNATIONAL MASTER BOILER-MAKERS' ASSOCIATION

Spring of 1909, Convention in Louisville, Ky. Secy., Harry D. Vought, 95 Liberty St., New York. Standardizing of Blue Prints for Building of Boilers; Boiler Explosions; Best Method of Applying Flues, Best Method for Caring for Flues While Engine is on the Road and at Terminals and Best Tools for Same; Flexible Staybolts Compared with Rigid Bolts; Best Method of Applying and Testing Same; Steel vs. Iron Flues, What Advantage and What Success in Welding Them; Best Method of Applying Arch Brick; Standardizing of Shop Tools; Standardizing of Pipe Flanges for Boilers and Templets for Drilling Same; Which is the long way of the Sheet; Best Method of Staying the Front Portion of Crown Sheet on Radial Top Boiler to Prevent Cracking of Flue Sheet in Top Flange; Rules and Formulas; Senate Bill.

IOWA RAILWAY CLUB

February 12, Des Moines.

LOUISIANA ENGINEERING SOCIETY

March 8, annual meeting, 323 Hibernia Bldg., New Orleans. Secy., L. C. Datz.

MASSACHUSETTS STREET RAILWAY ASSOCIATION

February 10, March 10, Boston. Secy., Charles S. Clark, 70 Kilby St.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS

March 3, New York. Secy., C. C. Hildebrand, 7 E. 42d St.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION

February 9, Auditorium Hotel, Chicago, Ill. Secy., Albert Stritmatter, Cincinnati, O.

NEW ENGLAND ASSOCIATION OF GAS ENGINEERS

February 17, Boston, Mass. Secy., N. W. Gifford, 26 Central Sq., E. Boston.

NEW ENGLAND RAILROAD CLUB

February 9, Young's Hotel, Boston, Mass. Paper: Steel Rails, H. C. Boynton. Secy., Geo. H. Frazier, 10 Oliver St.

NEW ENGLAND STREET RAILWAY CLUB

February 25, American House, Boston, Mass. Secy., John J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION

February 10, March 10, regular meetings. Secy., Willard Kent, Tremont Temple, Boston, Mass.

NEW YORK ELECTRICAL SOCIETY

February 17, 29 West 39th St., New York. Secy., G. H. Guy.

NEW YORK RAILROAD CLUB

February 19, 29 W. 39th St. Secy., H. D. Vought, 95 Liberty St.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS

February 16, etc., weekly meetings, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NEW YORK TELEPHONE SOCIETY

February 16, 29 West 39th St., New York. Secy., T. H. Laurence.

NORTHERN RAILWAY CLUB

February 27, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWEST RAILWAY CLUB

March 9, St. Paul, Minn. Secy., T. W. Flannagan, Care Soo Line, Minneapolis.

NOVA SCOTIA SOCIETY OF ENGINEERS

February 11, monthly meeting, Halifax. Secy., S. Fenn.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

February 23, monthly meeting, Technical High School Hall, 8 p.m. Paper: Wireless Telegraphy, Walter W. Massie. June 22, annual meeting. Secy., T. M. Phetteplace.

PURDUE MECHANICAL ENGINEERING SOCIETY

February 17, etc., fortnightly meetings, Purdue University, Lafayette, Ind., 6:30 p.m. Secy., L. B. Miller.

RAILWAY CLUB OF PITTSBURGH

February 26, monthly meeting, Monongahela House, Pittsburgh, Pa., 8 p.m. Secy., J. D. Conway, Genl. Office, P. & L. E. R. R.

RENSSELAER SOCIETY OF ENGINEERS

February 12, etc., fortnightly meetings, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

ROCHESTER ENGINEERING SOCIETY

February 12, monthly meeting. Secy., John F. Skinner, 54 City Hall.

ST. LOUIS RAILWAY CLUB

February 12, monthly meeting, Southern Hotel. Secy., B. W. Frauenthal.

SCRANTON ENGINEERS' CLUB

February 18, Board of Trade Bldg. Secy., A. B. Dunning.

TECHNICAL SOCIETY OF BROOKLYN

February 19, March 5, bi-monthly meetings, Arion Hall, Arion Pl., Brooklyn, N. Y., 8:30 p.m. Pres., M. C. Budell.

TECHNOLOGY CLUB OF SYRACUSE

March 9, monthly meeting, 502 Bastable Blk., 8 p.m. Secy., Robert L. Allen.

WASHINGTON SOCIETY OF ENGINEERS

February 16, George Washington University, 8 p.m. Paper: Overflow Lands of the Yazoo Delta, V. H. Manning. Secy., John C. Hoyt, 1330 F St., N. W., Washington, D. C.

WESTERN RAILWAY CLUB

February 16, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Jos. W. Taylor, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS

February 12, Electrical Section; February 17, extra meeting; Paper: Manganese Steel, W. S. Potter. March 3, regular meeting; Paper: The Chicago Harbor and River, John M. Ewen. Secy., J. H. Warder, 1737 Monadnock Blk., Chicago.

OFFICERS AND COUNCIL

PRESIDENT

Jesse M. Smith..New York

VICE-PRESIDENTS

L. P. Breckenridge ....Urbana, Ill.
Fred J. Miller ....Center Bridge, Pa.
Arthur West ....E. Pittsburg, Pa.

Terms expire at Annual Meeting of 1909

Geo. M. Bond...Hartford, Conn.
R. C. Carpenter..Ithaca, N. Y.
F. M. Whyte. ....New York

Terms expire at Annual Meeting of 1910

PAST PRESIDENTS

Members of the Council for 1909

Ambrose Swasey ....Cleveland, O.
John R. Freeman ....Providence, R. I.
Frederick W. Taylor ....Philadelphia, Pa.
F. R. Hutton ....New York
M. L. Holman..St. Louis, Mo.

MANAGERS

G. M. Basford ....New York
A. J. Caldwell ....Newburg, N. Y.
A. L. Riker ....Bridgeport, Conn.

Terms expire at Annual Meeting of 1909

Wm. L. Abbott...Chicago, Ill.
Alex. C. Humphreys ....New York
Henry G. Stott ....New Rochelle, N. Y.

Terms expire at Annual Meeting of 1910

H. L. Gantt..Pawtucket, R. I.
I. E. Moultrop..Boston, Mass.
W. J. Sando..Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

TREASURER

William H. Wiley ....New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt ....New York

HONORARY SECRETARY

F. R. Hutton.. New York

SECRETARY

Calvin W. Rice .... .29 W. 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
Alex. C. Humphreys
F. R. Hutton
Fred J. Miller
Frederick M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Edward F. Schnuck (2)
J. Waldo Smith (3)
Robert M. Dixon (4)
Waldo H. Marshall (5)

MEETINGS

Willis E. Hall (1), *Chairman*
Wm. H. Bryan (2)
L. R. Pomeroy (3)
Charles E. Lucke (4)
H. de B. Parsons (5)

PUBLICATION

Arthur L. Williston (1),
D. S. Jacobus (2) *Chairman*
H. F. J. Porter (3)
H. W. Spangler (4)
Geo. I. Rockwood (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Charles R. Richards (2)
Francis H. Stillman (3)
George J. Foran (4)
Hosea Webster (5)

LIBRARY

H. H. Suplee (1)
Ambrose Swasey (2)
Leonard Waldo (3)
John W. Lieb, Jr. (4), *Chairman*
Chas. L. Clarke (5)

HOUSE COMMITTEE

Henry S. Loud (1), *Chairman*
William Carter Dickerman (2)
Bernard Victor Swenson (3)
Francis Blossom (4)
Edward Van Winkle (5)

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Charles Wallace Hunt

On Affiliated Societies

F. R. Hutton, *Chairman*
R. H. Fernald
Alex. C. Humphreys
H. H. Suplee
F. W. Taylor

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
Charles Whiting Baker
L. D. Burlingame
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
R. C. Carpenter
Charles Wallace Hunt
J. W. Lieb, Jr.
Fred J. Miller

On Revision and Extension of the Code for Testing Gas Power Machinery

Charles E. Lucke, *Chairman*
E. T. Adams
Geo. H. Barrus
D. S. Jacobus
Arthur West

On Hudson-Fulton Celebration

Geo. W. Melville
M. L. Holman
Jesse M. Smith

SOCIETY REPRESENTATIVES
1909

On John Fritz Medal

Henry R. Towne (1) — F. R. Hutton (3)
Ambrose Swasey (2) — Charles Wallace Hunt (4)

On Board of Trustees United Engineering Societies Building

Chas. Wallace Hunt (1) — F. R. Hutton (2)
Fred J. Miller (3)

On Joint Library Committee

The Chairman of the Library Committee of The Am. Soc. M. E.

On National Fire Protection Association

John R. Freeman — Ira H. Woolson

On Joint Committee on Engineering Education

Alex. C. Humphreys — F. W. Taylor

On Government Advisory Board on Fuels and Structural Materials

Geo. H. Barrus — P. W. Gates
W. F. M. Goss

On Advisory Board National Conservation Commission

Geo. F. Swain — John R. Freeman
Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys — Fred J. Miller

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909

CHAIRMAN

F R. Low

SECRETARY

George A. Orrok

GAS POWER EXECUTIVE COMMITTEE

Prof. R. H. Fernald, *Chairman*
F. R. Hutton
H. H. Suplee
G. I. Rockwood
F. H. Stillman

GAS POWER MEMBERSHIP COMMITTEE

Robert T. Lozier, *Chairman*
D. B. Rushmore
F. S. King
George W. Whyte
Albert A. Cary

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
M. N. Latta
Chas. E. Sargent
F. P. Thorp
E. P. Coleman
C. L. Straub
W. T. Magruder
Arthur L. Rice

ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment

releasing the carriage gives the tool a chance to accurately face the shoulder, leaving a smooth surface instead of the ragged face left when carriage is released under full cut.

It has been the practice heretofore to arrange the positive stop a thirty-second of an inch beyond the knock-off for the feed, and in the usual operation of a machine of this kind the feed knocks off, and then the turret slide, released, jumps back, and the tool digs in, cutting a slight groove just back of the shoulder. When on work requiring exact shoulder distances or smoothly-finished shoulders, the operator brings the slide against the positive stop, holding it there with as nearly as possible uniform pressure until the turner has surely faced its full length. In the present machine the turret is always fed against the positive stop and held there with a uniform pressure, insuring the most accurate results for shoulder length.

Extracts from the book of the Hartness Flat Turret Lathe. Copies of the book mailed on request.

To Users of Taps and Dies

This Trade C Mark Means

"REGISTERED"

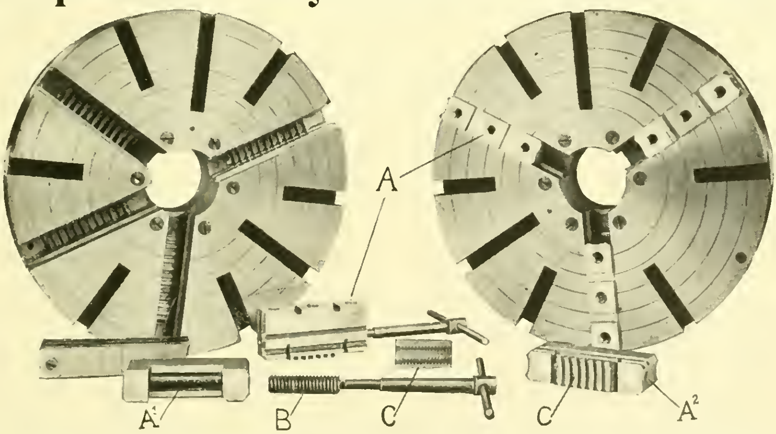
an absolute guarantee of first QUALITY

38 years on the market makes our Machine Screw Taps the pioneers in their class. They have no superiors, and are fully guaranteed

Taps and Dies furnished to A. S. M. E. Standard at regular prices

J. M. Carpenter Tap & Die Co., Pawtucket, R. I.

Improved Adjustable Jaw-Bases



This new cut, here first published, shows our Patent Convertible 2 and 3 Jaw Heavy Pattern Turret Lathe Chucks and the new Patent Independently Adjustable Jaw-Bases, which may be inserted interchangeably in Chucks of this type, when desired, in place of the regular forms of Jaws

FULL PARTICULARS AND PRICES UPON INQUIRY

THE D. E. WHITON MACHINE CO., New London, Conn., U. S. A.

LIBRARY OF ENGINEERING

The American Institute of Mining Engineers
The American Society of Mechanical Engineers
The American Institute of Electrical Engineers

The following volumes are needed to complete sets, and the Library wishes to secure them either by gift, exchange or purchase.

AMERICAN FOUNDRYMEN'S ASSOCIATION. *Journal.* Vol. 1–4: 5, Nos. 26, 28–30: 6, Nos. 31–35: 7, No. 41: Vol. 8, No. 48.

AMERICAN MACHINIST. Vol. 1–3.

AMERICAN SOCIETY OF NAVAL ENGINEERS. *Journal.* Vol. 1, parts 1 and 2, 1889.

CHEMICAL SOCIETY. London. *Journal.* Vol. 1–26.

DEUTSCHE CHEMISCHE GESELLSCHAFT. BERICHTE. Vol. 1–6. 1868–1874.

FOUNDRY. Vol. 1–22. 1892–1902.

THE GAS ENGINE. Cincinnati. Vol. 3–4. 1901–1902.

LE GÉNIE CIVIL. Paris. Vol. 1–23. Vol. 32.

INSTITUTION OF NAVAL ARCHITECTS. London. Transactions. Vol. 15, 1874.

INDUSTRIES AND IRON. London. Vol. 16–17. 1894.

MACHINERY. New York. Vol. 1, 1894.

JOURNAL OF PHYSICAL CHEMISTRY. Vol. 1–5, 1897–1901.

MINING AND SCIENTIFIC PRESS. Vol. 1–9, 11–19 (1860–1869): 24–33. 1872–1876.

NEUES JAHRBUCH FUR MINERALOGIE, GEOGNOSIE, GEOLOGIE UND PETREFAKTENKUNDE. 1836–38.

NEW ZEALAND MINES RECORD, WELLINGTON, N. Z. Vol. 1–6 , 1896–1902.

PHYSIKALISCHE ZEITSCHRIFT. Vol. 1–2. 1899–1900.

POWER, New York. Vol. 1–6. 1879–1885.

PRACTICAL ENGINEER. London. Vol. 5–6. 1888–1889.

PROGRESSIVE AGE. Vol. 1–14.

REVUE UNIVERSELLE DES MINES, ETC. Liége. Series 1: Vols. 1–4 of Series 2 (1857–78): Vols. 2, 9, 11, 15, and 18 of Series 3. Table des Matières de la première et de la seconde série (1857–76, 1877–87).

SOCIÉTÉ DE L'INDUSTRIE MINÉRALE. *Bulletin.* Series 1, Vol. 1–15: Series 2, Vol. 1–7.

6 *Atlas.* Part 2 of Vol. 11, 13, 14: also Part 26–33 of Vol. 2.

Compte Rendu. Jan. to March, 1879, and July, 1904.

SCIENCE. New Series. Vol. 1–6: 9 and 13.

SCIENTIFIC AMERICAN. First series. Vol. 1 and 2, 1845–1846.

SIBLEY JOURNAL OF ENGINEERING, Sibley College, Cornell University. Vol. 12, 1897–1898.

ZEITSCHRIFT FÜR ANGEWANDTE CHEMIE. Vol. 1–4, 1887–91.

ZEITSCHRIFT FÜR ANORGANISCHE CHEMIE. Vol. 22, 27, 29–38.

R. T. HILL. GEOLOGICAL HISTORY OF THE ISTHMUS OF PANAMA AND PORTIONS OF COSTA RICA.

——GEOLOGY AND PHYSICAL GEOGRAPHY OF JAMAICA.

Address the Secretary of

The American Society of Mechanical Engineers

29 West 39th St., New York

ADVERTISING SUPPLEMENT

SECTION 2

Power Plant Equipment

1909
CATALOGUE

SUPERSEDING ALL PREVIOUS ISSUES

S. F. HOUSTON
PRESIDENT

CARLISLE MASON
VICE-PRESIDENT

RUSSELL BONNELL
SECY. AND TREAS.

NELSON VALVE COMPANY

ESTABLISHED 1893
INCORPORATED UNDER THE LAWS
OF THE STATE OF PENNSYLVANIA
CAPITAL $1,000,000.

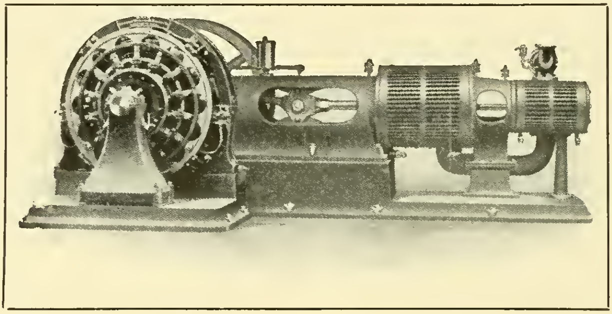
GENERAL OFFICES AND WORKS
WYNDMOOR
PHILADELPHIA, PA.

Be on time!
Write for this catalogue today
Simply say:
"Send 1909 Nelson Valve Catalogue"

ADDRESS
NELSOVAL
PHILADELPHIA

AND NELSON VALVE CODES

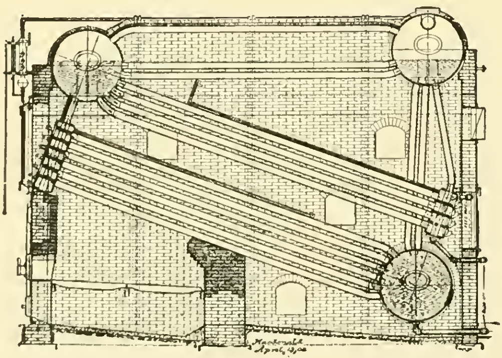
The balancing coils of a Ridgway Dynamo entirely neutralize the armature reaction. Result—sparkless commutation. Want to know more? Ask for Bulletins.



Ridgway Dynamo & Engine Co.

Ridgway, Penna.

ROBB-MUMFORD WATER TUBE BOILER

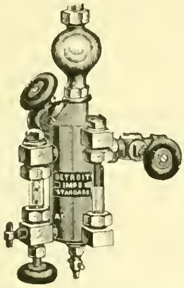


- Free expansion of tubes
- Perfect water circulation
- Dry or superheated Steam
- Half the usual number of handholes

Built in Canada by ROBB ENGINEERING CO., Ltd., Amherst, N. S.

ROBB-MUMFORD BOILER CO.

WORKS: SOUTH FRAMINGHAM, MASS.
SALES DEPARTMENT: 131 STATE STREET, BOSTON, MASS.
NEW YORK OFFICE: 90 WEST STREET



SOME ONE

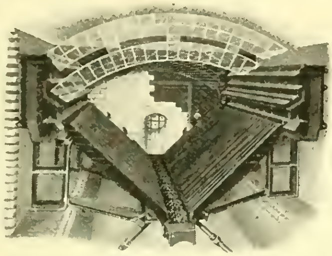
of the 337 styles and sizes of the Detroit Sight Feed Lubricators will fill any requirement you may have, and fill it well

Over One Million in Service on the World's Engines

The genuine is sold low enough. Do not accept substitutes on your specifications for contractors and dealers' profit

CATALOGUE ?

DETROIT LUBRICATOR COMPANY DETROIT, U. S. A.



Rear View

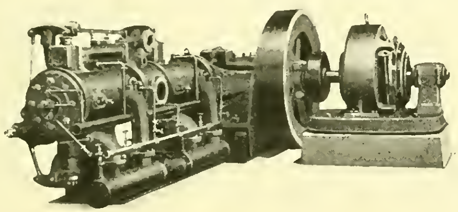
DETROIT AUTOMATIC STOKER

The special arch construction with supply of air under control produces higher efficiency and best results

Send for catalogue

DETROIT STOKER & FOUNDRY CO., DETROIT, MICH.

DU BOIS GAS ENGINES



The most improved design, developed under expert experience and a guaranteed commercial success.

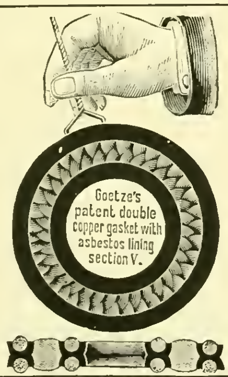
We build engines in sizes 5 to 375 horsepower—one, two and four cylinders, single acting, four cycle, horizontal types.

Electrical Service Engines, belted direct connected to generator. General Service Engines.

Write for our Catalog "M"

DU BOIS IRON WORKS, Du Bois, Pa.

Established 1877



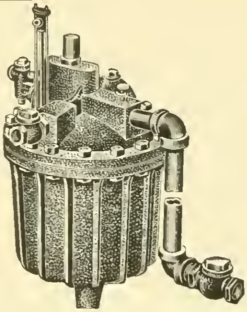
GOETZE'S ELASTIC COPPER GASKETS

will stop the leak and hold tight after all other means have failed. But why wait till then? Why not use Goetze's Gaskets at first?

WRITE FOR A FREE SAMPLE

American Goetze-Gasket & Packing Company

530 E. 149th St., New York City



Albany Steam Traps

are the result of thirty-five years specializing in the production of Steam Traps

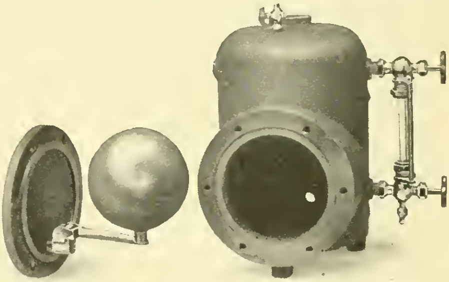
Owners and Engineers of Steam Plants are requested to write us for data concerning the

SPECIAL BUCKET RETURN TRAP

ALBANY STEAM TRAP CO., **Albany, N. Y.**

Established 1870. JAMES H. BLESSING, Pres. THOS. F. RYAN, Sec. and Treas.

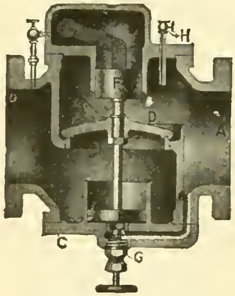
LINDSTROM'S CORLISS VALVE STEAM TRAP



JOHN T LINDSTROM

214 South Third Street

ALLENTOWN, PA.



HOCHFELDT
Back Pressure and Relief Valve

You have been looking for this

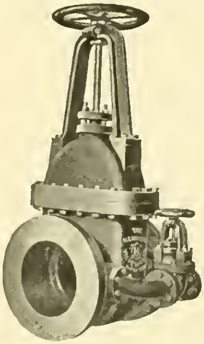
BACK PRESSURE VALVE

A Valve which can be used on either condensing or non-condensing systems. Instantly changed from one to the other. Send for catalogue of our Steam Specialties

Reducing Valves, Pump Regulators, Stop and Check Valves, Blow-off Valves, Etc.

THE JOHN DAVIS CO. **Chicago, Ill.**

New England Representative, W. G. Ruggles, 54 High St., Boston
New York Representative, J. H. Pearson, 122 Centre Street



FOR THE HIGHER THAN ORDINARY PRESSURES

GATE VALVES

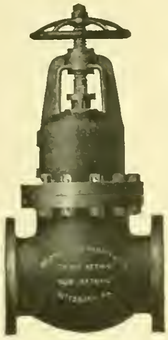
with double discs, taper seats, and central ball bearing seating device, are the tightest by reason of their flexibility and compensating features, off-setting strains, expansions, etc.

Catalogue explains merits of Construction and Operation

The KENNEDY VALVE MANUFACTURING CO.

Elmira, N. Y. and 57 Beekman St. New York City

Agencies in Chicago, San Francisco, Portland, Ore., New Orleans, Louisville, Ky., Boston.



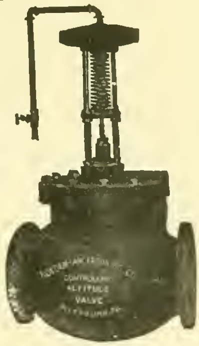
The Anderson

TRIPLE ACTING
Non-Return VALVES
"Work Both Ways"

Protect Your Power Station with the Valves that are Absolutely Guaranteed

Armour & Co. Chicago, ordered 321 10" Triple Valves

GOLDEN-ANDERSON Valve Specialty Co.
1032 Fulton Building
Pittsburg, Pa.



The Controlling Altitude Valve

maintains a uniform stage of water in standpipes, reservoirs or tanks.

NO FLOAT FIXTURES

No overflow in case of fire. Pressure. Valves closed by water and electricity

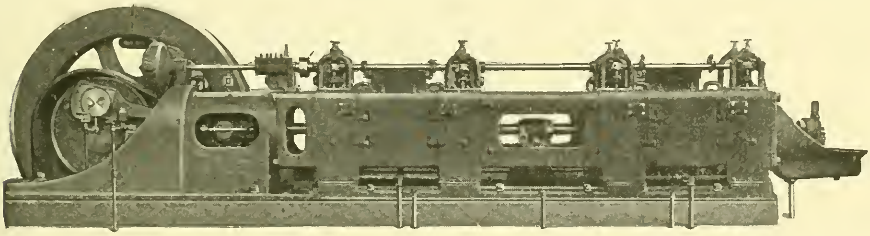
Valves and Traps
For Steam and Water Service

GRAPHITE LUBRICATION

GRAPHITE has within late years taken its place among recognized lubricants, but its ability to perform useful, efficient and satisfactory service depends upon its quality and formation.

DIXON'S FLAKE GRAPHITE has won recognition from engineers throughout the world. We have two particular booklets that may be of interest to you: "Graphite as a Lubricant" speaks of graphite lubrication at large and gives directions for its application in modern machinery; "Study in Graphite" is a verbatim report from Prof. W. F. M. Goss containing the results of his tests made with Dixon's Flake Graphite. We should be glad to send either or both of these booklets to you upon request.

JOSEPH DIXON CRUCIBLE CO., Jersey City, N. J.

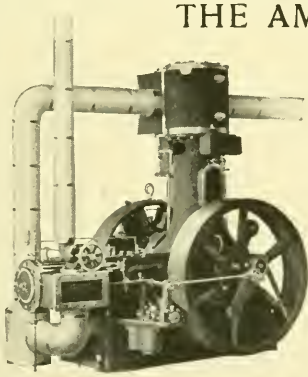


RIVERSIDE HEAVY DUTY DOUBLE-ACTING TANDEM GAS ENGINE (CLASS F)

Riverside Heavy Duty Gas Engines give steam engine service. Built in twelve types, seventy-two different sizes from 10 to 2500 H. P.

RIVERSIDE ENGINE COMPANY Oil City, Pennsylvania

THE AMERICAN BALL ANGLE COMPOUND ENGINE



is built for those discriminating buyers who appreciate the difference between an engine running at high speed and a REAL high speed engine.

Our designers threshed out problems of steam economy, balancing, close governing, lubrication, etc., before most modern engines were put on the market and in these American-Ball Angle Compounds, our latest product, we have embodied a simplicity of operation, reliability, astonishingly small cost of maintenance and other refinements, which easily make them the best high speed engines of their power.

You can get desirable qualities in the AMERICAN-BALL BEARING ANGLE COMPOUND ENGINE that you cannot get elsewhere.

Write for our special Bulletin No. 14 wherein all these points are fully discussed.

American Engine Co.
42 Raritan Avenue, Bound Brook, N. J.

Junior, Associate and Member Badges

The emblem of the Society, the conventionalized four-leaf clover, can be furnished promptly to members, mounted on a stick pin, with a catch-pin fastening, or in the form of a watch charm.

The Juniors' badge is now uniform with the Members' except that the enamel is crimson instead of blue. Old Junior badges will be redeemed. Authorized prices for both Junior and Member badges are

Stick pin - - -	$3.25
Vest pin - - - -	3.25
Watch charm - -	4.75

ADDRESS

The American Society of Mechanical Engineers

29 WEST 39 STREET, NEW YORK

ADVERTISING SUPPLEMENT

SECTION 3

Hoisting and Conveying Machinery
Power Transmission

E. C. & M.—MAGNETS

ARE MORE DEPENDABLE THAN YOUR CRANES

THEY WILL SAVE YOUR MONEY

USE THEM

THE ELECTRIC CONTROLLER & MFG. CO.

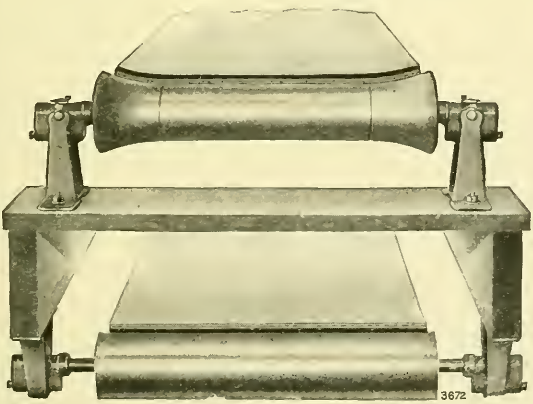
CLEVELAND OHIO

LINK-BELT COMPANY

PHILADELPHIA - - CHICAGO - - INDIANAPOLIS

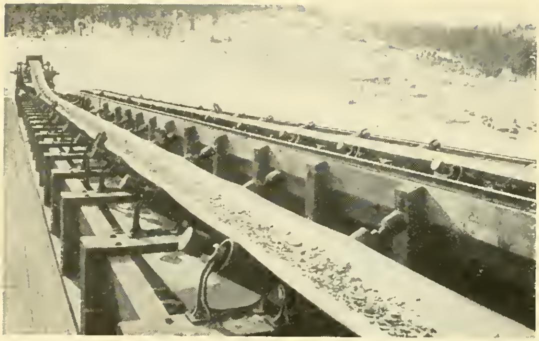
IMPROVED BELT CONVEYOR IDLER

PATENTED



Made of pressed steel, with closed ends—fixed to through shafts which turn in dust-proof bearings.

Write for details



Jeffrey

"Century" Rubber Belt

Conveyers

for handling

Coal, Ores, Sand, Gravel and package materials of all kinds

See Catalog K! 80

JEFFREY MANUFACTURE INCLUDES THE FOLLOWING LINES

ELECTRIC LOCOMOTIVES

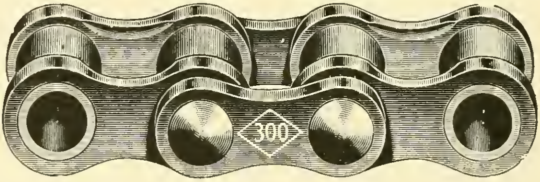
for Mine and Industrial Haulage

Coal Tipples, Car Hauls, Coal Washeries, Screens, Crushers, Drills, Coal Cutters, Elevators, Mine Fans, Cages, Hoists, Etc.

THE JEFFREY MFG. COMPANY

COLUMBUS, OHIO

New York	**Boston**	**Knoxville**
Chicago	**Pittsburg**	**Charleston, W. Va.**
St. Louis	**Denver**	**Montreal, Can.**



DON'T USE BELTS ON SHORT DRIVES

If you run them loose, there's a power loss from slip. Run them tight, and the loss shows up as extra journal friction, a worn bearing, and perhaps as a "hot box." There is no happy medium. The efficiency changes with the initial tension. But you still lose as long as there is any initial tension at all.

There is no initial tension on a DIAMOND CHAIN DRIVE, no power consumed except in doing useful work. If you want machines with troubleless and cool bearings, low internal friction, speed like clock-work; if you haven't time to waste with dope and lacings, if you like a compact neat drive, and want the most reliable transmission that your money will buy, give Diamond Chain a trial on one machine.

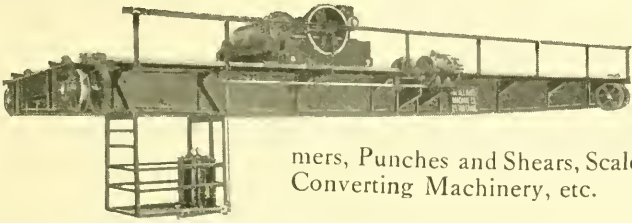
Write for book "Power Chains and Construction of Sprockets."

DIAMOND CHAIN & MFG. CO.

259 West Georgia St., Indianapolis, Ind.

Capacity 8,000,000 ft. per year.

ALLIANCE CRANES All Types



Also Rolling Mill and Hydraulic Machinery, Steam Hammers, Punches and Shears, Scale Cars, Copper Converting Machinery, etc.

THE ALLIANCE MACHINE CO. ALLIANCE, OHIO

Pittsburg Office, Frick Building. Birmingham Office, Woodward Building

---

THE J. M. DODGE COMPANY

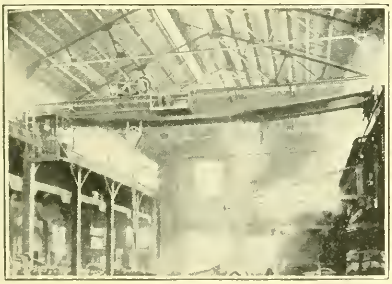
NICETOWN, PHILADELPHIA

CONTRACTING ENGINEERS.

"The Dodge System" of Coal Storage

Cranes, Bridge Tramways, Telphers and other apparatus for the transportation of material

Concrete and Steel Structures



WHITING ELECTRIC TRAVELERS and other cranes facilitate production. First class construction. Catalogue 45 illustrates different types. Our general catalogue describes modern foundry equipment.

Complete Foundry Plants

WHITING FOUNDRY EQUIPMENT CO.

Manufacturers, Engineers, Designers

HARVEY, ILL. (Chicago, suburb)

They've been tried and tested and actually do better work at a reduced cost. All types and capacities for all purposes.

CLEVELAND CRANES

Just send us your specifications or notify us in order that we may show you why, where and how "Cleveland Cranes" are considered best. You will be the gainer.

THE CLEVELAND CRANE & ~~CAR CO.~~ ENGINEERING CO.

— WICKLIFFE, OHIO. —

ADVERTISING SUPPLEMENT

SECTION 4

Engineering Miscellany

CENTRIFUGAL PUMPING MACHINERY

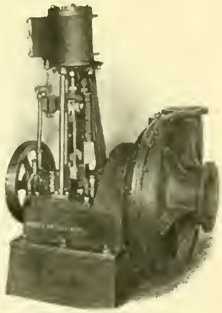
Of all Descriptions

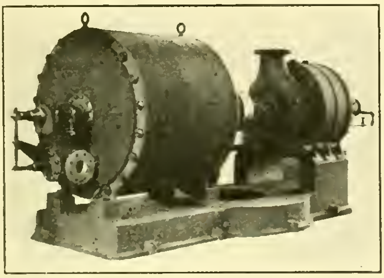
MORRIS MACHINE WORKS

BALDWINSVILLE, N. Y.

HENION & HUBBELL, Agents, 61-69 N. Jefferson Street, Chicago, Ill.

New York Office, 139-41 Cortlandt Street





One of our turbine pumps installed for the Mississippi River Commission for dredging work. Capacity 1200 g. p. m., against 468 ft. head.

KERR TURBINE CO.

WELLSVILLE, N. Y.

THE JEANESVILLE IRON WORKS CO.

HAZELTON, PA.

Builders of

High-Grade Pumping Machinery
Direct-Acting, Fly-Wheel and Centrifugal

for

Elevator, Mine and Waterworks Service

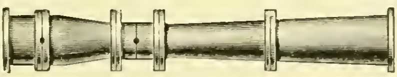
VENTURI METERS

are successful for measuring

HOT WATER FOR BOILER FEED

CALCIUM CHLORIDE BRINE

SODIUM CHLORIDE BRINE



VENTURI METER TUBE

because there is no mechanism in the Meter-Tube, which is the only part through which the liquid flows

Bulletins Nos. 21 and 33 sent on request

BUILDERS IRON FOUNDRY - - PROVIDENCE, R. I.

ENGINEERING SCHOOLS AND COLLEGES

CLARKSON SCHOOL OF TECHNOLOGY

Thomas S. Clarkson Memorial

ORGANIZED UNDER CHARTER OF THE UNIVERSITY OF THE STATE OF NEW YORK. Courses leading to degrees of Bachelor of Science in Chemical, Civil, Electrical and Mechanical Engineering, comprising four years of thorough training and resident college work in theory and practice of engineering. Copies of Clarkson Bulletin, published quarterly, mailed on application. WM. S. ALDRICH, *Director*.

POTSDAM, N. Y.

POLYTECHNIC INSTITUTE OF BROOKLYN

COURSE IN MECHANICAL ENGINEERING. Evening Post-Graduate Courses. Fred. W. Atkinson, Ph.D., President; W. D. Ennis, Member A. S. M. E., Professor Mechanical Engineering.

TUFTS COLLEGE

DEPARTMENT OF ENGINEERING. Civil, Mechanical, Electrical and Chemical Engineering. New laboratories and excellent equipment. Beautiful site within four miles of Boston. Preparatory department for students who have had engineering practice, but insufficient preparation for college work. For information concerning courses and positions of graduates, address,

PROF. G. C. ANTHONY, *Dean*.

TUFTS COLLEGE P. O., MASS.

THE RENSSELAER POLYTECHNIC INSTITUTE

Courses in Civil, Mechanical and Electrical Engineering and General Science leading to the degrees, C.E., M.E., E.E. and B.S.

Unsurpassed laboratories for Mechanical and Electrical Engineering.

Catalogue sent upon application, Troy, N. Y.

THE UNIVERSITY OF MICHIGAN

Ann Arbor, Mich.

DEPARTMENT OF ENGINEERING. Courses offered in Civil, Mechanical, Electrical, Chemical, Marine Engineering and Naval Architecture, Architecture and Architectural Engineering, and Geological Engineering. Four, five and six year courses. University attendance 5000; Engineering attendance 1350.

For special Bulletins address,

JAMES P. BIRD, *Secretary*.

NEW YORK UNIVERSITY SCHOOL OF APPLIED SCIENCE

DEPARTMENTS OF Civil, Mechanical and Chemcal Engineering.

For announcements or information, addres

CHARLES HENRY SNOW, *Dean*

UNIVERSITY HEIGHTS, N. Y. CITY.

PROFESSIONAL CARDS

THE ARNOLD COMPANY

Engineers—Constructors

Electrical—Civil—Mechanical

181 LaSalle Street, CHICAGO

EARLE C. BACON

Member A. S. M. E.

Hoisting, Crushing and Mining Machinery

Havemeyer Building, NEW YORK.

BERT. L. BALDWIN

Member A. S. M. E. and A. I. E. E.

Plans, Specifications and Superintendence of Manufacturing Buildings, Plants and Equipments of same.

Perin Building, CINCINNATI, OHIO.

D. HURLEY & COMPANY

Factory and Mill Engineering.

17 Custom House Street, PROVIDENCE, R. I.

CHAS. T. MAIN

Member A. S. M. E.

Mill Engineer and Architect.

Room 911, 45 Milk Street, BOSTON, MASS.

J. G. O'NEIL

Member A. S. M. E.

Contracting Engineer; Boilers, Engine Pumps and Steam Specialties.

304 The Rookery, CHICAGO, ILL.

CLASSIFIED LIST OF ADVERTISERS

AIR CONDITIONING.

Carrier Air Conditioning Co., New York.

AIR WASHING.

Carrier Air Conditioning Co., New York.

ARBORS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

AUTOMATIC STOKERS.

Detroit Stoker & Foundry Co., Detroit, Mich.

BARRELS, TUMBLING.

Whiting Foundry Equipment Co., Harvey, Ill.

BELTING CHAIN.

Link Belt Co., Philadelphia, Pa.

BELTING, LEATHER.

Schieren Co., Chas. A., New York.

BLOWERS, POSITIVE PRESSURE.

American Gas Furnace Co., New York.

BLOW PIPES AND BLOWERS.

American Gas Furnace Co., New York.

BLUE PRINTING MACHINES.

Buckeye Engine Co., Salem, O.

BOILERS.

Heine Safety Boiler Co., St. Louis, Mo.
Murray Iron Works Co., Burlington, Iowa.
Robb-Mumford Boiler Co., S. Framingham, Mass.

BORING MILLS.

Manning, Maxwell & Moore, New York.

BOLTS AND NUTS.

Russell, Burdsall and Ward Bolt and Nut Co., Port Chester, N. Y.

BOLT AND NUT MACHINERY.

Manning, Maxwell & Moore, New York.
National Machinery Co., Tiffin, O.

CAR HAULS, WIRE CABLE.

Jeffrey Mfg. Co., Columbus, O.

CARS, SCALE.

Alliance Machine Co., Alliance, O.

CASE HARDENING MACHINES.

American Gas Furnace Co., New York.

CASTINGS, SPECIAL HEAVY.

Hooven, Owens & Rentschler Co., Hamilton, O.

CENTERING MACHINES.

Whiton Machine Co., D. E., New London, Conn.

CHAINS, DODGE, EWART, LEY, MONOBAR, RENOLD, Etc.

Link Belt Co., Philadelphia, Pa.

CHAIN DRIVES.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHAINS, SPROCKET.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHUCKS, DRILL.

Morse Twist Drill & Machine Co., New Bedford, Mass.
Whiton Machine Co., D. E., New London, Conn.

CHUCKS, LATHE.

Whiton Machine Co., D. E., New London, Conn.

CLUTCHES, FRICTION.

Dodge Mfg. Co., Mishawaka, Ind.

COAL AND ASHES HANDLING MACHINERY.

Link Belt Co., Philadelphia, Pa.

COAL CUTTERS.

Jeffrey Mfg. Co., Columbus, O.

COAL STORAGE.

Dodge Co., J. M., Philadelphia, Pa.

COMPRESSORS, AIR.

Riverside Engine Co., Oil City, Pa.

COMPRESSORS, GAS.

Riverside Engine Co., Oil City, Pa.

CONDENSERS, SURFACE, JET AND BAROMETRIC.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

CONVEYING MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

COOLING.

Carrier Air Conditioning Co., New York.

COPPER CONVERTING MACHINERY.

Alliance Machine Co., Alliance, O.

COUNTERBORES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

COUNTERSHAFTS.

Builders Iron Foundry, Providence, R. I.
Dodge Mfg. Co., Mishawaka, Ind.

COUPLING, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

CRANES.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Dodge Co., J. M., Philadelphia, Pa.
Link Belt Co., Philadelphia, Pa.
Manning, Maxwell & Moore, New York.
Whiting Foundry Equipment Co., Harvey, Ill.

CUPOLAS, FOUNDRY.

Whiting Foundry Equipment Co., Harvey, Ill.

CUTTERS, MILLING.

Morse Twist Drill & Machine Co., New Bedford, Mass.

DEHUMIDIFYING.

Carrier Air Conditioning Co., New York.

DRILLS.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.

DRILLS, PORTABLE.

General Electric Co., Schenectady, N. Y.

DRAFTSMAN'S SQUARE.

Kelsey, D. J., New Haven, Conn.

DYNAMOS.

General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELECTRICAL MACHINERY.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELEVATORS.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

ELEVATING AND CONVEYING MACHINERY.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

ENGINEERS.

Arnold Co., The, Chicago, Ill.
Bacon, Earle C., New York City.
Baldwin, Bert L., Cincinnati, O.
Dodge, J. M. Co., Philadelphia, Pa.
Hurley, D. & Co., Providence, R. I.
Link Belt Co., Philadelphia, Pa.
Main, Charles T., Boston, Mass.
O'Neil, J. G., Chicago, Ill.

ENGINEERING COLLEGES.

Clarkson School of Technology, Potsdam, N.Y.
New York University, New York City.
Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Rensselaer Polytechnic Institute, Troy, N. Y.
Tufts College, Tufts College, Mass.
University of Michigan, Ann Arbor, Mich.

ENGINES, GAS.

Buckeye Engine Co., Salem, O.
DuBois Iron Works, DuBois, Pa.
National Meter Co., New York.
Riverside Engine Co., Oil City, Pa.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

ENGINES, STEAM.

American Engine Co., Bound Brook, N. J.
Buckeye Engine Co., Salem, O.
Hooven, Owens & Rentschler Co., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Ridgway Dynamo & Engine Co., Ridgway, Pa.
St. Louis Iron & Machine Works, St. Louis, Mo.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

FILES.

American Swiss File and Tool Co., New York.
Reichhelm & Co., E. P., New York.

FORGES, GAS.

American Gas Furnace Co., New York.

FOUNDRY EQUIPMENT.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, ANNEALING AND TEMPERING.

American Gas Furnace Co., New York.

FURNACES.

Whiting Foundry Equipment Co., Harvey Ill.

FURNACES, GAS.

American Gas Furnace Co., New York.

GAS GENERATORS.

American Gas Furnace Co., New York.

GASKETS.

American Goetze-Gasket & Packing Co., New York.

GASKETS, COPPER.

American Goetze-Gasket & Packing Co., New York.

GAS PRODUCERS.

Struthers-Wells Co., Warren, Pa.

GAGES, WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Manning, Maxwell & Moore, New York.

GEAR CUTTING MACHINES.

Manning, Maxwell & Moore, New York.
Newark Gear Cutting Machine Co., Newark, N. J.
Whiton Machine Co., D. E., New London, Conn.

GEARS.

Dodge Mfg. Co., Mishawaka, Ind.

GENERATING SETS.

American Engine Co., Bound Brook, N. J.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

GOVERNORS, PUMP.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.

GRAPHITE.

Dixon Crucible Co., Jos., Jersey City, N. J.

GRINDERS, TOOL.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Pratt and Whitney Co., Hartford, Conn.

GRINDING AND POLISHING MACHINERY.

Builders Iron Foundry, Providence, R. I.

HAMMERS, STEAM.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

HANGERS, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

HEATERS, FEEDWATER.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

HEATING MACHINES.

American Gas Furnace Co., New York.

HOISTING AND CONVEYING MACHINERY.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTS.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTS, MAGNETIC.

Electric Controller and Mfg. Co., Cleveland, O.

HUMIDIFYING.

Carrier Air Conditioning Co., New York.

HUMIDITY CONTROL, AUTOMATIC

Carrier Air Conditioning Co., New York.

HYDRAULIC MACHINERY.

Alliance Machine Co., Alliance, O.

INJECTORS.

Detroit Lubricator Co., Detroit, Mich.
Manning, Maxwell & Moore, New York.
Ohio Injector Co., Wadsworth, O

LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.
Warner & Swasey Co., Cleveland, O.

LATHES, BENCH.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, CHUCKING.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, TURRET.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, FOOT POWER.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, ENGINE.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, WOOD.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LOCOMOTIVES. ELECTRIC.

Jeffrey Mfg. Co., Columbus, O.

LUBRICANTS.

Dixon Crucible Co., Jos., Jersey City, N. J.

LUBRICATORS.

Detroit Lubricator Co., Detroit, Mich.
Ohio Injector Co., Wadsworth, O.

MACHINERY DEALERS.

Manning, Maxwell & Moore, New York.

MAGNETS, LIFTING.

Electric Controller and Mfg. Co., Cleveland, O.

MANDRELS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

METAL, ANTI-FRICTION.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METALS, BEARING.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METERS, VENTURI.

Builders Iron Foundry, Providence, R. I.

METERS, WATER.

National Meter Co., New York.

MILLING MACHINES.

Manning, Maxwell & Moore, New York.

MOTORS, ELECTRIC.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

OILING DEVICES.

Detroit Lubricator Co., Detroit, Mich.

PIPE CUTTING AND THREADING MACHINES.

Manning, Maxwell & Moore, New York.

PRESSES, HYDRAULIC.

Alliance Machine Co., Alliance, O.

PISTONS, METAL FOR FACING.

Allan & Son, A., New York.

PAPER MILL MACHINERY.

Sandusky Foundry & Machine Co., Sandusky, O.

PLANERS, METAL.

Manning, Maxwell & Moore, New York.

PULLEYS.

Dodge Mfg. Co., Mishawaka, Ind.

PUMPS, CENTRIFUGAL.

Jeanesville Iron Works Co., Hazleton, Pa.
Morris Machine Works, Baldwinsville, N .Y.
Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, GAS DRIVEN.

Riverside Engine Co., Oil City, Pa.

PUMPS, VACUUM.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, PRESSURE.

Wheeler Mfg. Co., C. H., Philadelph a, Pa.

PUMPS, TURBINE.

Kerr Turbine Co., Wellsville, N. J.

PUNCHES AND SHEARS.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

REAMERS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

REGULATORS, PUMP.

Davis Co., John, Chicago, Ill.

REGULATORS, FEED WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

RIVET HEADERS.

National Machinery Co., Tiffin, O.

RIVETERS, HYDRAULIC.

Alliance Machine Co., Alliance, O.

ROLLING MILL MACHINERY.

Alliance Machine Co., Alliance, O.

SCREW PLATES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

SEPARATORS, STEAM AND OIL.

Albany Steam Trap Co., Albany, N. Y.
Lindstrom, John T., Lancaster, Pa.

SHAPERS.

Manning, Maxwell & Moore, New York.

SMOKELESS FURNACE.

Detroit Stoker & Foundry Co., Detroit, Mich.

SOCKETS AND SLEEVES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

SPROCKETS.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

STEEL PLATE CONSTRUCTION.

Robb-Mumford Boiler Co., South Framingham, Mass.
Struthers-Wells Co., Warren, Pa.

STOKERS, MECHANICAL.

Detroit Stoker & Foundry Co., Detroit, Mich.

SUPERHEATERS.

Heine Safety Boiler Co., St. Louis, Mo.

TAPPING MACHINES AND ATTACHMENTS.

F. A. Errington, New York.

TAPS AND DIES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

TELPHERS.

Dodge Co., J. M., Philadelphia, Pa.

TRACK, INDUSTRIAL.

Whiting Foundry Equipment Co., Harvey, Ill.

TRAMWAYS, BRIDGE.

Dodge Co. J. M., Philadelphia, Pa.

TRAPS, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Lindstrom, John T., Lancaster, Pa.

TRANSMISSION MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Link Belt Co., Philadelphia, Pa.

TURBINES, STEAM.

General Electric Co., Schenectady, N. Y.
Hoover, Owens & Rentschler Co., Hamilton, O.
Kerr Turbine Co., Wellsville, N. Y.

TURRET LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Warner & Swasey Co., Cleveland, O.

UPSETTING AND FORGING MACHINES.

National Machinery Co., Tiffin, O.

VALVE DISCS, METALLIC.

Allan & Son, A., New York.

VALVES, AUTOMATIC.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BACK PRESSURE.

Davis Co., John, Chicago, Ill.
Kennedy Valve Co., Elmira, N. Y.
Walch & Wyeth, Chicago, Ill.

VALVES, BOILER STOP.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BLOW-OFF.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.

VALVES, CHECK.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, FLOAT.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, GATE.

Albany Steam Trap Co., Albany, N. Y.
Kennedy Valve Co., Elmira, N. Y.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, GLOBE.

Albany Steam Trap Co., Albany, N. Y.
Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, HYDRAULIC.

Nelson Valve Co., Philadelphia, Pa.

VALVES, NON-RETURN.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, RADIATOR.

Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.

VALVES, REDUCING.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

VALVES, REGULATING.

Davis Co., John, Chicago, Ill.

VALVES, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, SWING GATE.

Walch & Wyeth, Chicago, Ill.

WATER COOLING TOWERS.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

WATER TOWERS.

Struthers-Wells Co., Warren, Pa.

WATER COLUMNS.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.

WATER SOFTENERS AND PURIFIERS.

Dodge Mfg. Co., Mishawaka, Ind.

WHEELS, SHEAVE, SPROCKET, TRACTION.

Link Belt Co., Philadelphia, Pa.

WIRE NAIL MACHINES.

National Machinery Co., Tiffin, O.

WIRE ROPE.

Roebling's Sons Co., John A.

WOOD POLISHING WHEELS.

Builders Iron Foundry, Providence, R. I.

WOODWORKING MACHINERY.

Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.

WRENCHES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

ALPHABETICAL LIST OF ADVERTISERS

THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MARCH 1909

SPRING MEETING, WASHINGTON, D. C., MAY 4-7

MARCH 1909 VOL. 31 No. 3

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED AT 2427 YORK ROAD - - - - BALTIMORE, MD.
EDITORIAL ROOMS, 29 W. 39TH STREET - - - - NEW YORK

CONTENTS

Contents continued on next page

THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.
Price, one dollar per copy—fifty cents per copy to members. Yearly subscription, $7.50; to members, $5.
Application filed for entry at the Postoffice, Baltimore, Md., as second-class mail matter under the act of March 3, 1879

CONTENTS—Continued

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 MARCH 1909 NUMBER 3

SPRING MEETING

MAY 4–7, WASHINGTON, D. C.

THE chairman of the Meetings Committee, Mr. Willis E. Hall, and the Secretary, attended a meeting, February 17, of members residing in Washington and vicinity who met to organize a local committee and prepare the program for the Spring Meeting. It was voted that all members in Washington and vicinity be considered the local committee. Mr. Walter A. McFarland was chosen permanent chairman and it was voted that he appoint the necessary committees for the organization of the work.

The Society has received a very cordial invitation from the Washington Society of Engineers to hold its convention in Washington. They have appointed the following committee to coöperate with the Local Committee of our Society: W. A. McFarland, A. H. Raynal, W. E. Schoenborn, W. B. Upton, Mem. Am. Soc. M. E.; H. W. Fuller, Mem. Am. Inst. E. E.; John C. Hoyt, Assoc. Mem. Am. Soc. C. E.; D. S. Carll, Mem. Am. Soc. C. E.

The Society has also received the following invitation from the University Club of Washington:

Mr. Calvin W. Rice, Secy.
American Society of Mechanical Engineers
29 West 39th Street, New York

Dear Sir:

In connection with the spring meeting of the Society of which you are Secretary, which has been announced to be held in Washington, D. C., I beg to extend

to the Society through you an invitation on behalf of the University Club of Washington to make the club your headquarters for committee meetings, informal receptions and as a general bureau of information.

I regret that the club building is not of sufficient size to invite the Society to hold its main meetings therein, but we will be glad to extend to all members of the Society the privileges of the club as guests.

Very truly yours,
(*Signed*) PROCTOR L. DOUGHERTY
Chairman House Committee

A definite program cannot be announced in this issue of The Journal but it is hoped that it will be completed in season for publication in the April number.

On account of the many points of interest in Washington the members will be provided, through the kindness of the Washington members, a condensed handbook of the most interesting points in the city together with such information as to hours buildings are open, routes, etc., as will enable the guests of the convention to visit the places independent of parties. Excursions will also be organized and guides furnished so that members may look forward to a most profitable meeting.

The local headquarters will be at the New Willard Hotel and that hostelry has every intention of caring for most of the members, but it must be definitely understood that it cannot do so unless the members do their part by engaging rooms two weeks in advance. The Society cannot attend to the matter of engaging rooms for members at the hotel. As Congress will be in session, it is imperative that each member make arrangements for his accommodations as early as possible.

MONTHLY MEETING FOR FEBRUARY

The monthly meeting for February was held in the Engineering Societies Building on Tuesday evening, February 23, the subject for discussion being Safety Valves. This proved to be a subject in which there was unusual interest and the data presented by the several speakers were evidently appreciated. Until recently there have been no definite data upon the performance and capacities of safety valves and it is believed that the need of such information for engineers was so forcibly brought out at this meeting, that the results of other tests either under way or contemplated will be made available for engineers in the near future.

In spite of its being a rainy evening the meeting was well attended and speakers were present from several different cities, one coming

from Chicago, two from Boston, and others from Philadelphia, Hartford, Bridgeport, Albany and other places. The meeting was opened by Mr. Frederic M. Whyte, General Mechanical Engineer of the New York Central Lines, with a paper upon Safety Valves, giving special attention to locomotive practice. He was followed by Mr. L. D. Lovekin, Chief Engineer of the New York Shipbuilding Co., Camden, N. J., with a contribution relating to marine practice, by Mr. Philip G. Darling, Mechanical Engineer, Manning, Maxwell and Moore, upon Safety Valve Capacity, Mr. A. B. Carhart, Superintendent, Crosby Steam Gage and Valve Co., upon Safety Valve Springs, Mr. E. A. May, Engineer of the American Radiator Co., upon Low Pressure Practice, and other prominent engineers.

Over twenty engineers participated in the discussion, some having carefully prepared manuscripts, and a number of contributed discussions were sent by engineers who were unable to be present.

Meeting of the Engineering Profession on the Conservation of Natural Resources, March 24, 1909

In place of the regular meeting of the Society in March there will be a meeting under the auspices of the four national engineering societies; the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, and this Society, on the general subject of the Conservation of Natural Resources. All engineers and the public are invited.

The following program has been arranged and will be presented by representatives of the four Societies:

The American Society of Civil Engineers, The Conservation of Water, by John R. Freeman.

The American Institute of Mining Engineers, The Conservation of Natural Resources by Legislation, by Dr. Rossiter W. Raymond, Sec. A. I. M. E.

The American Society of Mechanical Engineers, The Waste of our Natural Resources by Fire, by Charles Whiting Baker, Mem. Am. Soc. M. E.

The American Institute of Electrical Engineers, Electricity and the Conservation of Energy, by Lewis B. Stillwell, Mem. A. I. E. E.

The committee of our Society assisting in the arrangement of the meeting consists of Geo. F. Swain, *Chairman*, Charles Whiting Baker, L. D. Burlingame, M. L. Holman and Calvin W. Rice.

GENERAL NOTES

THE HUDSON-FULTON CELEBRATION

The program for the celebration of the centenary of the opening of steam navigation by Robert Fulton on the Hudson River, and for the third centenary of the discovery of the river by Henry Hudson, has been announced. The entire Hudson valley will take part in this celebration, which will begin September 25 and continue until October 9. There is to be a naval parade up the river, among the participants in which will be a facsimile of Fulton's first steamboat, the Clermont, and a facsimile of Hudson's Half-Moon, the first ship to enter the river. This facsimile of the Half-Moon is now being built by the people of Holland.

THE GAS POWER SECTION

At the meeting of the Gas Power Executive Committee, January 27, the Meetings, Membership, Literature, Installations and Plant Operations Committees were appointed for the year 1909. A list of the committees is given in another department.

The work of these committees is already under way, and it is expected that considerable work will have been completed before the Spring Meeting. The Meetings Committee has secured a few good papers, and several more are promised. None of these however are sufficiently advanced to publish at this time. The Membership Committee with its enlarged personnel has completed its organization and good results are being obtained.

The Nominating, Accident and Tellers Committees will be announced later.

ACTIVITIES OF THE STUDENT BRANCH OF STEVENS INSTITUTE

The Student Branch of Stevens Institute of Technology has adopted a Constitution and has begun very active meetings. A series of general lectures was opened by Calvin W. Rice, Secretary Am. Soc. M. E., on Engineering as a Vocation; and other addresses have been made by Mr. Geo. L. Fowler, Member Am. Soc. M. E., upon

Locomotives and their Latest Improvements; by Mr. C. J. Armstrong, Consulting Engineer of the Singer Building, on Skyscrapers; by Mr. Ferdinand Stark of the Camera Club of New York, on Photography; by Dr. Pond on Commercial Manufacture of Sulphuric Acid, and by Professor Ganz on Electrolysis. They have also made several inspection trips.

Lectures in advance have been scheduled as follows: The Conservation of the Natural Resources of America, by a member of the National Commission, Washington, D. C.; The Conquest of the Air, Messrs. Post and Guy, Aëro Club of America; Wireless Telegraphy, Dr. Fred Vreeland, M.E.

In connection with the work of the Branch the students have organized an employment bureau for the purpose of assisting students to obtain positions during summer vacations and to enable them to use their spare time during the college year in some useful and remunerative occupation.

COMMITTEE OF AWARD SMITHSONIAN INSTITUTION

Prof. John A. Brashear, lately elected Honorary Member of this Society, is one of the Committee of Award appointed by the Regents of the Smithsonian Institution, controlling the award of the Hodgins Gold Medal for the promoting of Aërodromics and Aviation.

Other members of the Committee are, Octave Chanute, Chairman, Alexander Graham Bell, Major George O. Squier and James Means.

Members of the Society will recall that the John Fritz medal was conferred upon Dr. Bell at the dedication of the Engineering Societies Building in 1907, and that Major George O. Squier presented a very exhaustive paper upon aëronautics at the last annual convention.

PAST-PRESIDENT OF THE SOCIETY ON THE ASSAY COMMISSION

Mr. Ambrose Swasey, Past-president of the Society, was appointed by President Roosevelt on the Annual Assay Commission, to examine and test the fineness and weight of the coins reserved by the several mints of the United States during the year 1908.

The members of the Commission met in Philadelphia February 10, for the purpose of counting, weighing and assaying the sample coins which had been set apart as representing the gold and silver pieces coined at the several mints during the past year.

PROFESSOR OF CIVIL ENGINEERING AT HARVARD

Prof. Geo. F. Swain, for several years Professor of Civil Engineering, Massachusetts Institute of Technology, has received the appointment of Professor of Civil Engineering at the Engineering School at Harvard. Professor Swain is a graduate of the Institute of Technology and supplemented his studies by three years at the Royal Engineering School at Berlin. He became instructor in the Institute in 1881 and since 1887 has been professor of civil engineering there. From 1880 to 1884 he was an expert on water power for the tenth census. In 1887 he was appointed consulting engineer of the Massachusetts Railroad Commission and has exerted a marked influence on railway bridge work and as engineer on numerous special commissions on elimination of grade crossings, etc. He has been a member of the Boston Transit Commission since its organization in 1894 and has carried on a private engineering practice mainly on bridge work. He is Vice-President of the American Society of Civil Engineers and Chairman of the Committee on Cement Tests in that Society, and is Chairman of the Committee on Conservation of Natural Resources of this Society.

MEMBER AM. SOC. M. E. PRESIDENT CHAMBER OF COMMERCE IN PARIS

M. Laurence V. Benet, Mem. Am. Soc. M. E., who has represented the Society upon several occasions in Paris, France, has been reëlected President of the American Chamber of Commerce in that city. Since the founding of the Chamber of Commerce in 1894, a president has not held office for a longer period than two terms of one year each. To M. Benet, who has already served two terms, reëlection comes as a special compliment.

MUSEUM OF SAFETY AND SANITATION IN THE ENGINEERING SOCIETIES' BUILDING

The executive office for the administrative and promotive work of the Museum of Safety and Sanitation has been opened in the Engineering Societies' building. Prof. F. R. Hutton, Honorary Secretary of the Society, is chairman of the committee on plans for the association and scope of its work.

The other members of the committee are Dr. Thomas Darlington, of the Health Department of the city of New York, P. T. Dodge, president of the Engineers Club, William J. Moran, attorney-at-law,

and Henry D. Whitfield, architect. Mr. Frank A. Vanderlip has accepted the office of treasurer. Mr. Charles Kirchoff, Mem. Am. Soc. M. E., editor of The Iron Age, is chairman of the committee of direction, T. C. Martin, editor of The Electrical World, vice-chairman, and Dr. William H. Tallman, director.

The society has for its aim the prevention of disablement and death by accident where safety devices for dangerous machines and preventable methods of combating dread diseases may be used.

WORLD CONFERENCE ON CONSERVATION

It was suggested by the North American conference on the conservation of natural resources, that the United States issue invitations to all the nations of the world to send delegates to an international world conference on conservation to be held at The Hague next September. The President immediately accepted the suggestion, and Secretary of State Bacon began the preparation of the invitations which will be issued as early as possible.

Delegates from Mexico and Canada and the United States attended the international congress, and those assembled in the East Room at the White House included members of the Cabinet, Justices of the Supreme Court of the United States, representatives of foreign governments, senators, representatives, members of the National Conservation Commission, representatives of the engineering societies and experts on the natural resources of the country.

The first result which the world conference would expect to obtain is a general inventory of the natural resources of the world, and of what has been done by the different nations in the way of conservation; the ways and means of securing proper use of the resources with a view to replenishing wherever possible, and to preventing waste of those which cannot be renewed.

INTERNATIONAL CONFERENCE AT THE WHITE HOUSE, FEB. 18, 1909

The International Congress on the Conservation of Natural Resources was held at the White House, February 18, 1909. The chairman of the Committee of the Society on the Conservation of Natural Resources, Professor Swain, Chairman of the Meetings Committee, Mr. Willis E. Hall, and the Secretary, attended the conference of the delegates from Canada, Mexico and the United States. President Roosevelt in addressing the assembled delegates said in part:

I feel, that this conference is one of the important steps that have been taken of recent years looking towards the harmonious coöperation between the nations of the earth for the common advancement of all.

In international relations I think that the great feature of the growth of the last century has been the mutual recognition of the fact that instead of its being normally to the interest of one nation to see another depressed, it is normally to the interest of each nation to see the others uplifted. I believe that the movement which you initiate is of the utmost importance to this hemisphere and may be of the utmost importance to the world at large.

I am anxious to do all in my power to work in harmony for the common good of all instead of each working to get something at the expense of the other. Ultimately, each of us will profit immeasurably if instead of striving to advance by trampling down the other all strive to advance together for the common advancement.

This is peculiarly an engineering problem and must be worked out by engineers, having in mind the public good solely and the permanent greatness of our country. Surely our Society could not be engaged in a more useful work.

At the request of the National Commission our Society has appointed an advisory committee consisting of Geo. F. Swain, J. R. Freeman and Chas. T. Main, with whom the Government is conferring in connection with water powers. The above gentlemen have made personal sacrifice to represent the Society and to attend to this patriotic duty.

INDUSTRIAL EDUCATION

A commission was appointed by the state legislature last April to investigate industrial education, and it has just submitted its report. The method employed by the committee was the sending out of letters to employers and employees throughout the state. Replies were received from over 2000 firms employing about 250,000 people. All of these replies expressed the need for industrial schools of some kind, but the consensus of opinion was against trade schools,—that is, schools in which shop work predominates. Their objections are largely based upon the belief that such schools would be too expensive, and would reach but a comparatively small percentage of the population. There is also an objection to the partial-time school; the reason given being that this system would disorganize factories and shops.

New Jersey was the first state in the union to make provision for industrial schools, as is pointed out in the report. It began by the passage of a law in 1881, and the movement has developed into the Newark Technical School, the Trenton School of Industrial Art and the Industrial School of Hoboken.

The report shows that the following states have taken legislative action: Massachusetts, New York, Wisconsin, Connecticut, Georgia, Alabama and Oklahoma. In Massachusetts over 2500 pupils are already enrolled in industrial schools. Alabama has nine schools and Georgia has eleven district agricultural schools.

PRESIDENT OF THE UNIVERSITY OF MICHIGAN RESIGNS

James Burrell Angell, LL.D., has submitted his resignation of the Presidency of the University of Michigan to take effect next June. The Board of Regents created the office of Chancellor and offered it to Dr. Angell at a salary of $4000 a year, together with the continued use of the President's mansion on the university campus.

Dr. Angell, who on Jan. 7 last celebrated his eightieth birthday, has directed the growth of the University since 1871, when he came from the Presidency of the University of Vermont. The University of Michigan had then 1110 students; the attendance has now reached 4780.

ANNUAL DINNER OF THE ALUMNI OF STEVENS INSTITUTE

Among those who spoke at the annual dinner of the Alumni of Stevens Institute of Technology held in New York, February 19, were the following: Mr. Alex. C. Humphreys, Mem. Am. Soc. M. E., President of Stevens Institute, Mr. Alfred Noble, Mem. Am. Soc. M. E., Past-President, Mr. H. G. Prout, and Mr. John A. Bensel.

OTHER SOCIETIES

CONVENTION OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION

The Annual Convention of the American Foundrymen's Association and allied bodies, including the Foundry and Manufacturers Supply Association, the American Brass Founders Association and the Associated Foundry Foremen, will be held in Cincinnati, with Hotel Sinton as headquarters, May 18, 19 and 20. Exhibits of foundry equipment and supplies, conducted by the Foundry and Manufacturers Supply Association will be open for inspection the entire week of May 17, in the Music Hall.

ANNUAL MEETING OF THE CANADIAN SOCIETY OF CIVIL ENGINEERS

The 23d annual meeting of the Canadian Society of Civil Engineers was held at Toronto, in the King Edward Hotel, on January 28, 29 and 30 with President Galbraith and Secretary McLeod as the presiding officers.

Reports of the year's work of the Toronto, Quebec and Winnipeg branches of the society were presented. Printed reports of the Council and of committees for the past year were submitted for discussion. After the annual luncheon the report of the Committee on the Establishment of Testing Laboratories was submitted.

The society met at 7.30 p.m. in the convocation hall of Toronto University to listen to an interesting address by the retiring president, Dr. John Galbraith, upon the education and duties of the engineer. After Dr. Galbraith had been thanked for his efficient administration of the society affairs in the past year, the members became the guests of the undergraduates of the Faculty of Applied Science of the University at the 20th annual dinner. A handsome service of silver was presented by the students to Dr. Galbraith.

On Friday, January 29, there was an excursion to Port Colborne and Welland. In the evening the annual dinner of the society was given in the King Edward Hotel. On Saturday, the election of officers for the coming year was held and the business of the meeting concluded. The following officers were elected:

President, Geo. A. Mountain, of Ottawa.
Vice-Presidents: G. J. Desbarats of Quebec, H. N. Ruttan of Winnipeg, W. F. Tye of Montreal.
Members of Council: C. R. Contlee of Ottawa, F. W. W. Doane of Halifax, A. E. Dounect of Quebec, N. J. Ker of Ottawa, R. S. Lea of Montreal, J. G. Legrand of Montreal, Duncan MacPherson of Ottawa, R. A. Ross of Montreal, J. E. Schwitzer of Winnipeg.

MOVEMENT FOR ESTABLISHMENT OF TESTING LABORATORIES IN CANADA

At the annual meeting of the Canadian Society of Civil Engineers, the report of a committee on the establishment of testing laboratories was submitted. They recommended that the Dominion government be approached with reference to the establishment of a department of research similar to that lately established by the American government under the United States Geological Survey, in order to investigate the properties of all materials of engineering interest, whether in the raw or manufactured form.

Pending the establishment of a national laboratory of research by the government, the society suggested that arrangements might be made with universities of Canada whereby their staffs and equipment may be utilized to some extent for the purpose.

The committee closed their report by the expression of a belief that the encouragement of such laboratories will materially assist in the development of the natural resources of Canada.

The address of the retiring president, Dr. John Galbraith, was upon the education and duties of the engineer.

WESTERN SOCIETY OF ENGINEERS

At the February 3d meeting of the Western Society of Engineers, held in the society's rooms in Chicago, Mr. Horace E. Horton presented a paper on Water Storage in Elevated Tanks and Stand-Pipes, which was discussed by Messrs. T. W. Snow, Whyte, Naylor, Storey, W. W. Curtis and C. B. Burdick.

ANNUAL MEETING OF ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS

The annual meeting of the Illinois Society of Engineers and Surveyors was held January 27 to 29, at the Great Northern Hotel, Chicago, Ill. The annual presidential address was delivered by Mr.

Charles B. Burdick, on the subject of Government Control of Public Utilities, and reviewed the growth of these utilities and the resultant problems. The necessity of government control was pointed out, especially where questions of public health are concerned, as in the case of water supply and sewage systems. The report of the Committee on Sewers reviewed the competition between pipe, brick and concrete as materials for sewer construction. This report was followed by papers on Sewers. After the reading of several miscellaneous papers, the report of the Committee on Water-Works was presented, followed by a paper on the Lake View Pumping Station (Chicago).

Papers on Streets and Roads were also presented, and the report of the Committee on Roads and Pavements was accompanied by detailed tables as to the use of different kinds of fillers for brick paving. Reports were also submitted by the Committee on Drainage, the Committee on Railways and a special committee on Engineering Investigations.

The following were elected officers for the coming year: President, John B. Hittell; Vice-President, John W. Woermann; Secretary, E. E. R. Tratman.

THE AUTOMOBILE CLUB OF AMERICA

The Automobile Club of America held a session of their Fourth Annual Meeting in the rooms of the Society in the Engineering Societies Building; the invitation to use the Society's headquarters being extended by Professor F. R. Hutton, Honorary Secretary.

Mr. Henry Souther, Mem. Am. Soc. M. E., had charge of a running series of dynomometer tests on the club's apparatus during the convention. Papers were presented on the Economics of Weight Reduction by F. B. Howell, Mem. Am. Soc. M. E., and An Improved Type of Compression Coupling, by W. S. Noyes, Mem. Am. Soc. M. E.

At the Annual Banquet, Mr. Jesse M. Smith, Pres. Am. Soc. M. E., was a special guest. Seventy-seven members and guests of the Automobile Club attended, the largest number that has ever been present at the yearly gatherings. Other members of this Society present were: Henry Hess, A. L. Riker, Prof. R. C. Carpenter, Henry Souther, John Wilkinson, H. E. Coffin, C. S. Mott, C. E. Davis, Henri G. Chatain, A. H. Raymond, and Bruce Ford.

ANNUAL MEETING OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The annual meeting of the American Society of Civil Engineers was held on Jan. 20 at the house of the Society in New York, Mr. Charles Macdonald, presiding.

It was announced that the annual convention would be held in the Mt. Washington Hotel, Bretton Woods, N. H.

The secretary announced the appointment and organization of the special committee to report on the design, ultimate strength and safe working values of steel columns and struts. Among the members of this committee, the following are members of this Society: Mr. A. L. Bowman, *Chairman,* Mr. A. P. Boller and G. F. Swain. The Chairman of the Committee presented resolutions stating that no testing machine of sufficient size to make full-size tests of large compression members is in existence; that such a machine and tests are beyond the means of private interests; that the work could best be carried on by the Government, and asking that the latter be requested to proceed with the construction of such a machine. The resolution was adopted and copies voted to be sent to the President and Vice-President of the United States and the Speaker of the House of Representatives.

The following officers were elected: President, Onward Bates; Vice-Presidents, George H. Pegram and Emil Swensson; Treasurer, Joseph M. Knap; Directors, Francis L. Stuart, Samuel C. Thompson, William G. Wilkins, Arthur N. Talbot, William N. Gardner, and Horace A. Sumner.

MEETING OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The February meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineering Societies Building, New York, February 19, 1909. The secretary announced the election of 88 associate members.

Owing to the illness of Dr. Charles P. Steinmetz, consulting engineer of the General Electric Company, his paper entitled Prime Movers, was presented by Mr. Ernst J. Berg. Most of the discussion was contributed by Prof. Charles E. Lucke, of Columbia University, and Mr. Henry W. Longwell, of the Westinghouse Machine Company at East Pittsburg. Both Messrs. Lucke and Longwell freely criticised the subject matter of the paper, saying, in brief, that the authoritative statements in the paper were not new and that the other statements were inconclusive. Mr. Calvert Townley, of the New York,

New Haven & Hartford Railroad Company, in discussing the part of the paper relating to hydraulic motors, deplored the agitation now centering at Washington, D. C., to place all valuable water powers under federal control. In Mr. Townley's opinion the cost of developing and maintaining hydraulic power plants and the net revenue therefrom, are not such as to justify burdensome federal restrictions.

MEETINGS TO BE HELD IN THE ENGINEERING SOCIETIES BUILDING

The following meetings will be held in the Engineering Societies Building during February and March.

Date	Name	Secretary	Time
Mar. 2	N. Y. Society Accountants & Bkprs	T. L. Woolhouse	8:00
" 4	Blue Room Engineering Society	W. D. Sprague	8:00
" 5	Explorers Club	H. C. Walsh	8:30
" 9	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 9	American Soc. of Mech. Engrs	Calvin W. Rice	8:00
" 10	Illuminating Engineering Society	P. S. Millar	8:00
" 12	American Inst. of Electrical Engrs	R. W. Pope	8:00
" 16	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 16	N. Y. Telephone Society	T. H. Laurence	8:00
" 19	N. Y. Railroad Club	H. D. Vought	8:15
" 23	American Geographical Society	A. A. Raven	8:00
" 23	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 24	Municipal Engineer of N. Y.	C. D. Pollock	8:15
Apr. 1	Blue Room Engineering Society	W. D. Sprague	8:00
" 2	Explorers Club	H. C. Walsh	8:30
" 6	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 8	Illuminating Engineering Society	P. S. Millar	8:00
" 9	Amer. Institute of Electrical Engrs	R. W. Pope	8:00
" 13	N. Y. Soc. of Accountant & Bkprs	T. L. Woolhouse	8:00
" 13	Amer. Soc. of Mechanical Engineers	C. W. Rice	8:00
" 14	Optometrical Soc. of City of N. Y.	J. H. Drakeford	8:00
" 15	Musurgia Society	F. M. Frobisher	8:00
" 16	N. Y. Railroad Club	H. D. Vought	8:15
" 20	American Geographical Society	Geo. H. Hurlbut	8:00
" 20	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 20	N. Y. Telephone Society	T. H. Laurence	8:00
" 27	N. Y. Soc. of Accountants & Bkprs	T. L. Woolhouse	8:00
" 28	Municipal Engineers of N. Y.	C. D. Pollock	8:15

NECROLOGY

KENTON CHICKERING

Kenton Chickering, Vice-President of the Oil Well Supply Company, died December 9, 1908, at his residence in Oil City. He was born in Worcester, Mass., May 16, 1847, and received his education in the Massachusetts public schools.

In 1863 he became a dispatch bearer for General Clark of the United States commissary department in New York City, and remained in the Government service for a time after the war. In 1870 he represented Eaton and Cole, dealers in brass and iron goods, at Titusville, remaining with the company when it became Eaton, Cole and Burnham Company, with offices at Oil City. In 1878 Mr. Chickering was made secretary of the Oil Well Supply Company, Ltd., which was formed at this time. This new company absorbed the Eaton, Cole and Burnham Company and others. In 1891, when the Oil Well Supply Company was organized in its present corporate form, Mr. Chickering was elected Vice-President, the position which he held at the time of his death.

He patented a number of useful inventions in connection with oil well machinery, and planned the large manufacturing plant erected by the company in 1901–1902, known as the Imperial Works. He also designed a number of special machines to increase the output and improve the quality of product of the plant.

Mr. Chickering was very active in church, civic and fraternal organizations.

GEORGE W. WEST

George Washington West died at his home in Middletown, N. Y., December 24, 1908. He was born April 3, 1847, at Troy, N. Y., and received his early education in the public schools of that city. In 1865 he entered the service of the New York Central & Hudson River Railroad at Schenectady, as machinist, and was later made foreman and master mechanic, leaving this position to accept a similar one with the West Shore.

In 1886, he entered the employ of the New York, Lake Erie and Western, now the Erie, as master mechanic of the Mahoning division, was later transferred to the main shops at Meadville, Pa., and in 1888 to the Eastern division. From 1891 until the time of his death he held the position of superintendent of motive power of the New York, Ontario and Western.

Mr. West was past president of the American Railway Master Mechanics Association, a member and past-president of the New York Railroad Club, and past-president of the Central Railway Club. He was a member of the Masonic order and the order of Elks. The George W. West Association of Engineers at Carbondale was named for him. He was also a director of the First National Bank of Middletown, president of the Ontario and Western Savings and Loan Association, a member of the Middletown Club and a member of the Board of Water Commissioners.

WILLIAM S. HUYETTE

William S. Huyette was born in Blair, Neb., November 13, 1870, and was educated in the public schools of Detroit, Mich.

He began his shop experience in the drafting department of the Detroit Blower Company, under the management of his father. He was later engaged by the engineering firm of Gilbert Wilkes Company, Detroit, leaving their employ in 1897 to open an office for the Wickes Boiler Company in Milwaukee, Wis.

The following year, Mr. Huyette returned to Detroit, to take charge again of the business of the Gilbert Wilkes Company in the absence of Mr. Wilkes, who was commander of the Detroit Naval Militia during the Spanish-American War. Upon the return of Mr. Wilkes after the war, Mr. Huyette went back to his work with the Wickes Boiler Company, and opened their branch office in Chicago. He continued as manager of that office until his death, January 11, 1909.

His engineering work was chiefly with boiler installations, and he also designed and patented a gas engine and designed and built steel sail boats and motor boats.

He was a member of the National Association of Stationary Engineers, and of the Chicago Yacht Club.

WALTER MORRISON ALLEN

Walter Morrison Allen, works manager of the Warner & Swasey Co., died February 8 at his home in Cleveland, O. He was born in Bristol-

ville, O., December 14, 1866, and received his early education in the local schools of Cherryfield, Me.

He evinced an interest in mechanics early in life and when only sixteen years of age frequently went to the nearest railway station, a distance of thirty miles, to study and make drawings of the locomotives that passed that point. In 1885, he began work as an apprentice to the machinist's trade in the works of Messrs. Warner & Swasey. He was given special opportunities in the drafting room, and at the completion of his term of apprenticeship was kept in this department, of which he was made head in 1891. During the next two years, the details of the design and construction of the 26-in. telescope of the Naval Observatory and the 40-in. telescope of the Yerkes Observatory came largely under his direction.

In 1893 he had charge of the firm's exhibit at the Chicago exposition and during the following six years was superintendent of their works. In 1904 he was made works manager, the position which he held at the time of his death. He had traveled much in the interests of the company, visiting England and the Continent in 1897–1898 and again in 1900.

Mr. Allen was a member of Calvary Presbyterian Church, the Cleveland Engineering Society, the Cleveland Chamber of Commerce, the Colonial Club and the Automobile Club of Cleveland.

PERSONALS

Mr. Thomas D. Adams, formerly located at Southport, Conn., has accepted a position with Werner & Pfleiderer, Saginaw, Mich.

Mr. Chester B. Albree was elected one of the directors of the mechanical section of the Engineers' Society of Western Pennsylvania for the coming year.

Mr. L. M. Bannon has become assistant superintendent of the Union Bleaching and Finishing Co., Greenville, S. C. He was formerly associated with the Dexter Engineering Co., Providence, R. I., in the capacity of chief draftsman.

Mr. George H. Baush is no longer connected with Hill, Clarke & Co., as general manager. He has accepted a position with the Fay Machine Tool Co., Philadelphia, Pa.

Mr. John Birkinbine, Consulting Engineer, Philadelphia, Pa., has gone to Mexico to review the exploratory work which his son, J. L. W. Birkinbine, has carried on for a year and a half, for the Oaxaca Iron and Coal Co., Oaxaca, and to investigate railroad routes to make the coal and iron ore available. He will also look into some large hydro-electric improvements projected in the States of Oaxaca and Guerrero.

Mr. Henry A. Bogardus has organized Henry A. Bogardus & Co., with offices at 178 E. Huron St., Chicago, Ill. He was formerly connected with Jas. P. Marsh & Co., Chicago, as Manager.

Mr. David A. Chapman, recently with the Woonsocket Electric Machine & Power Co., Woonsocket, R. I. as supervising engineer, has become superintendent of the Estate of E. S. Converse Co., with office at 101 Milk St., Boston, Mass.

Mr. A. G. Christie, who was chief engineer of the Western Canada Cement and Coal Co., Exshaw, Alberta, Can., is now research assistant in steam engineering at the University of Wisconsin.

Mr. Charles O. Churchill has accepted a position with the Georgian Manufacturing Co., Binghamton, N. Y. He was formerly mechanical engineer of the valve department of the Fairbanks Co. of New York.

Mr. Howard E. Coffin has an article in the January 21 issue of The Automobile, on Impressions of an Automobile Engineer.

Mr. George N. Comly, who has been chief draftsman for the Solvay Process Co., for 14 years, has tendered his resignation to take effect March 1.

Mr. William W. Estes has accepted a position with the Taft-Pierce Co., Woonsocket, R. I., in the capacity of designer.

Mr. R. E. Fox, Jr., has recently been elected vice-president of The Engineer Company, New York. He was formerly secretary and sales manager of the company.

Mr. Herbert I. Gannett, formerly Manager of the Omaha, Neb., office of the Monarch Acetylene Co., is now vice-president and general manager of the Buffalo, N. Y., office.

Mr. James B. Haney, leading draftsman, office of Chief of Ordnance, U. S. A., Washington, D. C., will be located for some time at the McCundless Bldg., Honlulu, Hawaii.

Mr. William H. Hansell, until recently chief engineer of the Standard Roller Bearing Co., has opened an office with Mr. G. Edward Smith, in the Provident Bldg., Philadelphia, Pa., for consulting and contracting engineering. The firm name is Edward Smith Company.

Mr. Charles G. Herbert, Engineer, The Solvay Process Co., has removed from Detroit, Mich., to Syracuse, N. Y.

Prof. H. Wade Hibbard, formerly Professor of Mechanical Enginering of Railways, Sibley College, Cornell University, Ithaca, N. Y., has been appointed Professor of Mechanical Engineering, University of Missouri, Columbia, Mo.

The partnerships heretofore existing between Alexander C. Humphreys and Arthur G. Glasgow, both members of the Society, have been dissolved, owing to the decision to incorporate the firm of Humphreys & Glasgow of New York.

Dr. F. R. Hutton, Honorary Secretary of the Society, has revised and rewritten his text-book on The Mechanical Engineering of Steam Power Plants. The book gives a broad survey of the functions and general assembly of a power plant. This is its third edition.

Mr. Herman G. Jakobsson is no longer connected with the Bethlehem Steel Co. as chief ordnance draftsman but has entered the service of the Midvale Steel Co., Philadelphia, Pa.

Mr. James B. Ladd and David Baker have opened offices in the Real Estate Trust Bldg., Philadelphia, Pa., under the firm name of Ladd and Baker, and will carry on a general consulting and contracting engineering business.

Mr. J. S. Lane, formerly of the Webster, Camp & Lane Co., Akron, O., and consulting engineer in the city of New York, has lately become connected with The Engineer Company, Hudson Terminal Bldg., New York.

Prof. C. E. Lucke, head of the Department of Mechanical Engineering of the School of Mines, Engineering and Chemistry of Columbia University, spoke before the Society of Arts of the Massachusetts Institute of Technology, February 27, on the general subject of Gas Power.

The Railway Journal, in their January issue, publishes an extract of the paper on Articulated Compound Locomotives, presented at the Annual Meeting by C. J. Mellin.

The Water and Gas Review publish in their December number the paper on Reminiscences of a Gas Engine Designer, by L. H. Nash, presented at the Annual Meeting of the Society.

Mr. V. M. Palmer, until recently superintendent of the Smith Automobile Co., Topeka, Kans., has accepted a position as engineer with the Selden Motor Vehicle Co., Rochester, N. Y.

Mr. Charles E. Paul, formerly Assistant Professor of Mechanics and Materials, Pennsylvania State College, has been appointed Associate Professor of Mechanics at Armour Institute of Technology.

Mr. Edwin G. Rust, formerly Vice-President and general manager of the Elk Rapids Iron Co., Elk Rapids, Mich., has accepted a position with the Sheffield Coal and Iron Co., Sheffield, Ala.

Mr. Howard E. Satterfield, lately director of Winona Technical School, Indianapolis, Ind., is at present with the North Carolina College of Agriculture and Mechanic Arts, West Raleigh, N. C.

Mr. Samuel B. Sheldon, formerly associated with the Lackawanna Steel Co., Buffalo, as General Superintendent, has entered the service of the Bethlehem Steel Co., Saucon Works, in the same capacity.

Mr. Henry Souther, of Hartford, Conn., will devote considerable of his time to the interests of the Standard Roller Bearing Co., Philadelphia, Pa., as consulting engineer.

Dr. Charles P. Steinmetz, Schenectady, N. Y., gave a lecture on The Future of Electricity before the Society of Arts of the Massachusetts Institute of Technology, Boston, on the evening of January 28.

Prof. George F. Swain, at present in charge of the Department of Civil Engineering at Massachusetts Institute of Technology, has been appointed Professor of Civil Engineering in the Graduate School of Applied Science of Harvard University.

Mr. T. H. Tracy, who until recently was with the Tracy Engineering Co., Los Angeles, Cal., is now President of the Tracy-Devereaux Co., with offices at 211–15 Kerchoff Bldg., Los Angeles, Cal.

A. S. Vogt, Mechanical Engineer for the Pennsylvania Railroad Company, has recently taken on eight draftsmen. This appears to be an indication of the return of the railroad activity which marked 1907.

Power and the Engineer and The Electrical Review and Western Electrician have republished the article on Fuel Economy Tests at a Large Oil Burning Electric Plant by C. R. Weymouth, published in The Journal, and presented at the Annual Meeting.

Mr. Oliver B. Zimmerman has entered the employ of M. Rumely Co., La Porte, Ind., as chief draftsman. He was until recently associated with Hart-Parr Co., Charles City, Ia., in the same capacity.

TESTS UPON COMPRESSED AIR PUMPING SYSTEMS OF OIL WELLS

By Edmund M. Ivens, New Orleans, La.

Junior Member of the Society

When the Louisiana oil fields at Evangeline were in full operation, they offered exceptional opportunities for the study of air lifts. Nearly every known method of piping the wells was in use. The air plants originally installed were the crudest affairs imaginable, having been erected in feverish haste during the boom several years ago. When the production of the fields began to decrease, and the price of oil also declined, it was realized for the first time that the operating expenses were abnormal, and that unless greater economy were practiced, disastrous results would follow. Few changes were made, however, up to eighteen months ago, beyond the purchasing of additional equipment.

2 Each concern has a central station or air plant and all the compressors therein are connected to a manifold from which the air lines lead to the various wells on the property held by that concern. The manifold design is such that by manipulating the valves, any machine may be made to operate any of the wells.

3 Often the air lines reach the wells by a roundabout way, and have innumerable short bends, valves, double swings to avoid pipe cutting, and plugged tees instead of elbows. All of this tends further to decrease the economy of the operation, and taking all things into consideration, it is little wonder that the efficiencies of the plants were low. The size pipe used for these air lines is designed neither for the amount of air to be transmitted nor for the distance it is to be carried, but is with one exception 2 in. in diameter.

4 The boilers of the air plants are of 40 h.p., of a portable contracted waist type, and few were covered with asbestos. The boilers were so set that one-fifth of their lengths projected into the open, as

To be presented at the Spring Meeting of The American Society of Mechanical Engineers. All papers are subject to revision.

indicated in Fig. 1, in order to avoid the necessity of perforating the roof to receive the stacks and to provide cooler boiler-rooms, regardless of the heat wasted.

5 The redeeming feature in all the plants is the type of compressor in general use. These compressors are generally of high grade, and display remarkable endurance. It is common for a machine designed for 350-lb. pressure to operate under a pressure of 500 lb., and at speeds far in excess of those for which it was designed. The most popular type of compressor has the duplex steam end and compound or two-stage air end. The steam cylinders are fitted with Meyer adjustable cut-off valves and the air cylinders in some instances with piston and in others with Corliss intake valves and poppet discharge valves. Plain speed governors are used and the capacities of the

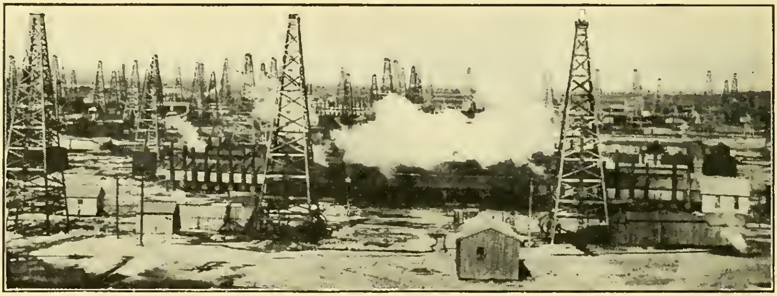


Fig. 1 A Typical Air Plant

compressors range from 100 to 1000 cu. ft. of free air per minute and operate at pressures of from 150 to 750 lb. per square inch. The machine best adapted to the purpose, however, is the 500 cu. ft., 500-lb. type.

TERMS

6 An explanation of certain terms to be used may not be out of place.

"Submergence in feet" refers to the number of feet below the surface of the fluid (after the well has been pumped down, and is operating under its normal conditions) that the air under pressure is admitted.

"Per cent of submergence" is the submergence in feet divided by the total number of feet of vertical discharge line, measured from the point of admission of the air to the point of discharge of the fluid.

"Volumetric efficiency" of the compressor is the actual amount of free air that is compressed and discharged by the cylinder, divided by the cubical contents of that cylinder.

"Free air" is air at standard temperature and pressure.

"Pumping head" is the vertical distance in feet (after the well is pumped down, as before stated) from the fluid level in the well to the point of discharge.

$$\text{"The Constant"} = \frac{\text{Gal. per minute} \times \text{pumping head in feet}}{\text{Cu. ft. of free air per minute}}$$

$$\text{"The Ratio"} = \frac{\text{Cu. ft. of free air per minute}}{\text{Cu. ft. of fluid per minute}}$$

DESCRIPTION OF SYSTEMS

7 Fig. 2, 3, 4, and 5, illustrate the air lift systems that are and have been in use on the oil fields.

8 Fig. 2 shows the Straight Air or Sanders system. The well top is sealed as shown at A. Compressed air is forced through the pipe B into the space between the discharge or eduction pipe C, and the well casing D.

9 When without air pressure the fluid in the well will stand at some point such as E, the level in the air space and the discharge line being identical. When air is forced through B, the level of the fluid in the air space is gradually forced down until the end of C is uncovered. Instantly some of the air escapes into the discharge pipe C, lowering the air pressure in the air space F. This causes the fluid to rise in and up the air space and discharge pipe until a point is reached where air and water pressure balance. Then, more air coming in, the pressure again rises, the fluid level is forced down as before, more air escapes into the discharge pipe, and thus the cycle is repeated. As may be readily seen, the air that rushes into the discharge line carries the "slug" of water that has just previously entered.

10 Fig. 3 shows what is commonly known as the Central Pipe system. The discharge line A is placed inside of the well casing as before and inside of the discharge is suspended a small air line usually $1\frac{1}{4}$ in. in diameter. The end of the $1\frac{1}{4}$ in. line is plugged and a number of $\frac{1}{8}$ in. holes are drilled inclining upwards in the last joint of pipe. Air is forced down through the small air line shown, passes out of the $\frac{1}{8}$-in. holes, and mingles with the fluid carrying it out through the discharge line A. It is generally supposed that the fluid in this

case is discharged because of the aëration of the fluid in the discharge pipe which in turn is caused by the intimate commingling of air and fluid. The weight of the fluid column inside of the discharge pipe is therefore less in pounds per square inch than that without and the energy due to this difference in weight is utilized to lift the fluid and overcome the various losses.

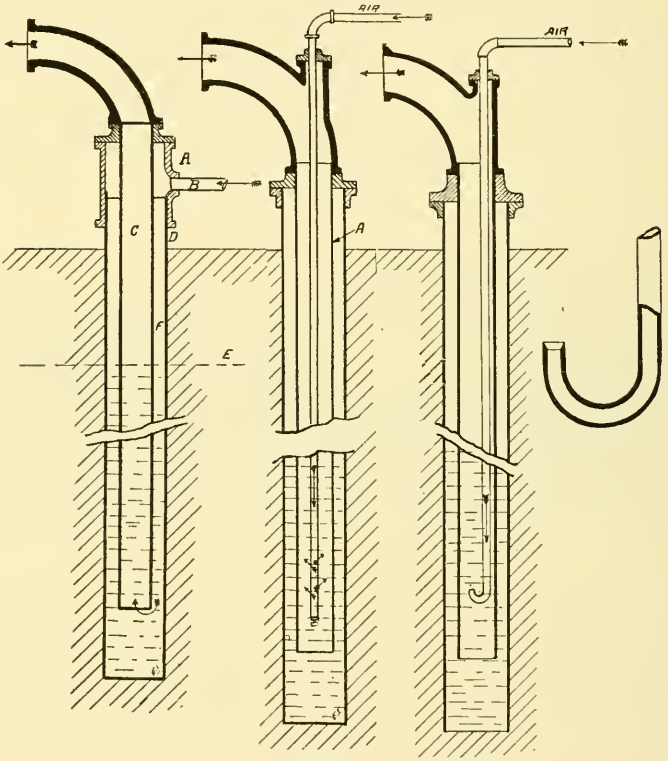


Fig. 2 Straight Air Lift System | Fig. 3 Central Pipe System | Fig. 4 Return Bend System

11 What is commonly known as the Open End system of air lift was at one time in quite extensive use on the field. It is similar to the system just described except that the small air line is open at the lower end, and of course there are no holes drilled in the air line.

12 Fig. 4 illustrates a form of the Return Bend system. It is claimed by the inventor that: "It consists in improved processes and

apparatus whereby the compressed air is delivered in bulk into the lower end of the water eduction pipe, and the water and air are caused to ascend through said pipe in distinct alternate layers of definite dimensions."

13 The use of this system has been discontinued in Evangeline because, as the field managers told the writer, it failed to produce as large a quantity of fluid as that produced by other systems.

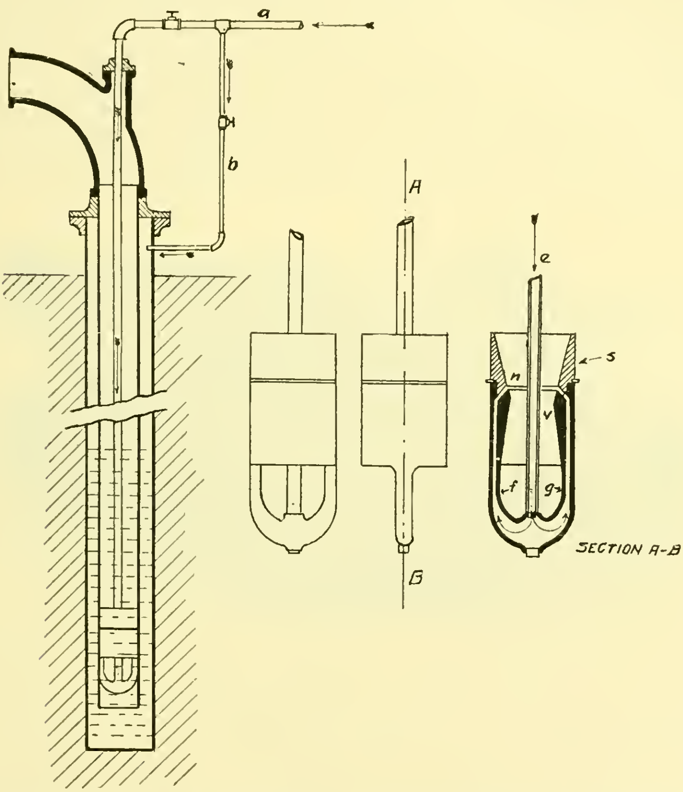


FIG. 5 SYSTEM COMBINING FEATURES OF OTHER SYSTEMS DESCRIBED

14 Fig. 5 shows a patent system which in reality is a combination of the several systems already described. The claims of the inventor are: less submergence, and hence less air pressure necessary, decreased air consumption, or with an equal amount of air, increased fluid yield.

15 Compressed air is forced through *a* down into the foot piece, which is placed at that point of submergence shown by test to be most economical. The well top is sealed and air under pressure

is also admitted between the casing and discharge pipe on the water head by means of the branch shown at *b*. This forces the fluid to a higher level in the discharge pipe and also prevents fluid in the air space or chamber from vibrating and foaming. This is quite an advantage in oil well pumping as the liability of making "riley oil" is thereby greatly lessened.

16 The footpiece shown in section is made of cast brass and is in two parts. The air on reaching the foot piece divides and goes up through the hollow prongs *f* and *g* and out the nozzle *n*. The nozzle is adjusted to receive the quantity of air to be used by screwing the upper part *s* of the footpiece, in or out as the case may be. To increase the velocity of the fluid in the discharge line, the footpiece is restricted and formed into a "venturi" as shown at *v*.

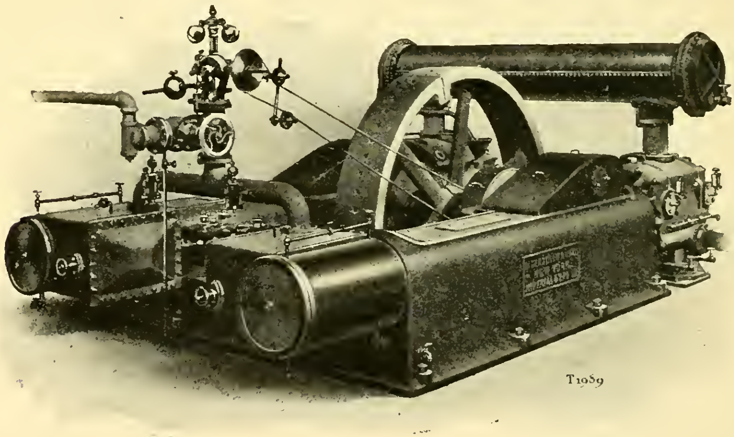


Fig. 6 Type of Compressor Used

Test No. 1

17 The Crowley Oil and Mineral Company was the first to take active steps for the improvement of their plant and pumping equipment. They decided to install the patent air lift last described (Fig. 5). A test of the old system was first made to determine the amount of compressed air used and the fluid yield. The new equipment was next installed and a similar test made of the same duration and under the same conditions. The tests and installation were conducted on Well No. 32, 1805 ft. deep, and located 542 ft. from the compressor operating it. The air to the well was controlled by means

of a manifold in the plant and was conveyed to the well top through a two-in. pipe line which as usual was in poor condition and badly designed.

18 The system of pumping was that illustrated in Fig. 2. The well casing was 6 in. in diameter, suspended inside of which was a 4-in. discharge line.

19 The compressor was a duplex steam and compound air type made by the Ingersoll-Rand Company and designed to compress 1000 cu. ft. of free air per minute to 350 lb. pressure. The steam end was fitted with Meyer adjustable cut-off valves and the air end with Corliss intake and poppet discharge valves. The machine is shown in Fig. 6.

20 The discharge pipe from the well top was run up into a steel tank of known dimensions and the amount of fluid pumped during the

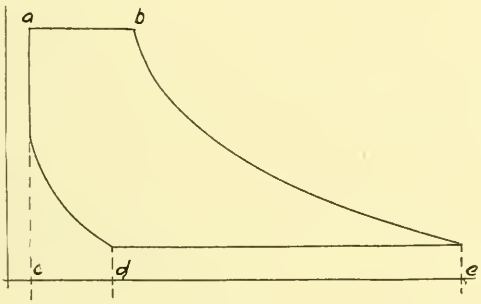


Fig. 7

test ascertained by direct measurement. Air gages, previously tested, were placed both at the compressor and at the well top thereby making it possible to determine the friction losses in the manifold and air line and also the actual pressure at the well top. Simultaneous indicator cards were taken from the steam and air ends of the compressor, and from these cards were obtained the volumetric and mechanical efficiencies, the steam and air horse powers, and the steam consumption (theoretical) of the machine.

21 The volumetric efficiency was assumed to be the ratio of the total piston displacement to the dsplacement at the point where the admission valve opens, ($\frac{de}{ce}$ on the indicator card, Fig. 7). Sometimes this method is inaccurate and unsatisfactory (1) because the entering air at atmospheric temperature and pressure is heated by

contact with the cylinder walls and piston; and (2) because of leakage of air from the compression side of the moving piston to the suction side. Neither the expansion resulting from the first condition nor the reduction in volumetric efficiency resulting from the second are observable on the indicator card.

22 The first inaccuracy was partially overcome by placing a recently calibrated thermometer as far down in the intake pipe of the compressor as possible, noting the temperature and making the necessary corrections as will be observed in the log of results.

23 The method of ascertaining the volumetric efficiency, that the writer would have used, but for his inability to obtain the necessary apparatus, was in brief as follows:

Connect the air discharge of the compressor to an enclosed tank. From this tank, connect to a cooler and from thence to a second enclosed tank of known dimensions.

Place a regulating valve between the first tank and the cooler, setting the valve to maintain the pressure in the first tank at that point at which the efficiency is to be determined.

Attach test gages to both tanks and a reliable thermometer to the second tank.

Start the compressor and note the temperatures of the intake air and of the air in the second tank both at the beginning and end of the run. Note also the initial and final air pressures and the reading of the barometer, and the speed in revolutions per minute of the compressor.

The volume of air compressed is then determined from the formula:

$$V = v \frac{273 + T}{R}\left(\frac{29.92 \times P_1}{273 + T_2} - \frac{29.92 \times P}{273 + T_1}\right)$$

where

V = Volume of air compressed.
v_1 = Cubical contents of the second tank.
T = Room, or intake air, temperature.
T_1 = Initial temperature of the air in the tank.
T_2 = Final temperature of the air in the tank.
R = Reading of the barometer in inches of mercury.
P and P_1 = Initial and final air pressures in the tank.

The volume of air thus obtained divided by the total piston displacement equals the volumetric efficiency.

OBSERVATIONS

24 Every thirty minutes for a period of six hours, readings were taken of the boiler pressure gage, the air gage at the compressor and at the well top, the r.p.m. of the compressor, the temperature of the intake air and of the barometer. A set of indicator cards, and also a sample of the fluid pumped from the well, were taken at each interval.

25 The temperature of each sample of fluid was noted; it was then placed in a proper receptacle, and at the end of the test, the weight of a gallon was ascertained, together with the specific gravity of the oil. The amount of fluid pumped was determined, as before stated, by direct measurement, due allowance having been made for the samples that were withdrawn.

26 When these tests were run, no attempt was made by the writer to re-design the air lines, or to correct in any manner the numerous other defects. The old system was tested just as it had been operated, and the new system was installed and tested under the same adverse conditions. After both systems had been tested, some few of the defects were corrected in the manifold and air line design, thereby insuring more economical operation in the future.

TABLE 1 SUMMARY OF RESULTS

The Crowley Oil and Mineral Company, Evangeline, La.

	Old System	New System
Duration of test, hours	5.5	6.0
Mean i.h.p.	122.56	89.19
Mean water h.p.	9.97	10.36
Mean air h.p.	107.38	79.16
Gallons of fluid per second	0.542	0.608
" " " " hour	1953.6	2188.2
Barrels of fluid per hour	46.51	52.1
Weight of 1 gal. of fluid	8.7	8.69
Mean temperature of fluid, deg. fahr.	111.5	113.2
Percentage of salt water in fluid	87.3	86.7
" " sand "	2.2	1.9
" " crude oil "	10.5	11.4
Barrels of oil per hour	4.86	5.94
Barometer reading, inches of mercury	29.95	29.94
Specific gravity of oil	0.9	0.9

	Old System	New System
Constant	63.1	101.8
Size of air line, inches		1.25
Total depth of well, feet	1805.0	1805.0
Size of casing, inches	6.0	6.0
Height above ground to which the fluid was pumped, feet	18.5	18.5
Size of discharge line used, inches	4	4
Total length of vertical discharge line	1513.5	1513.5
Total length of vertical air line in well	1513.5	1493.0
Dimensions of compressors, inches*	10x22x16x20	7½x18x16x20
Number operated	1	1
Kind of fuel used†	Crude oil	Crude oil
Gallons of fuel used per hour	48.36	35.27
Barrels of fuel used per hour	1.15	0.835
Price of 1 bbl. of oil at time of test, dollars	0.90	0.90
Cost of fuel for producing 1 bbl. of fluid, dollars	0.0222	0.0146
Cost of fuel for producing 1 bbl. of crude oil, dollars	0.212	0.126

*Type of compressor used, Rand Drill Co. Imperial Type X, Steam Cylinders, compound air cylinders.

†Type of boiler, oil well supply, portable contracted waste.

Test No. 2

WELLS NO. 12, 30, AND 32 OF THE CROWLEY OIL AND MINERAL COMPANY

27 The saving in air volume accomplished by the new system led those interested to endeavor to operate two wells with one machine, something before considered impossible in the field.

28 Well No. 30 was forthwith tested, though not with sufficient accuracy to warrant the publication of the results, and the approximate pumping head and submergence established. The new system was then installed with the requisite pipe to equalize the submergence (hence working pressure) of this well with that of No. 32. How successfully the working pressures of the two wells were equalized may be seen by reference to Table 2 of the Appendix.

29 The two wells in question were then connected to one air compressor with gratifying results. No trouble was experienced in starting, and the machine furnished air in abundance for steady operation.

30 Preparations were being made to run the usual test when the compressor operating Well No. 12 "went dead." This last named well had been previously tested and equipped with the new system. This shutdown, of course, would mean a loss of at least a day's pro-

duction from the well, amounting to quite an item, so the writer advised that this well be also connected to the machine already operating No. 30 and No. 32. By speeding the machine up a few revolutions, the additional load was easily taken care of as may be more fully noted by reference to the accompanying log (Table 2).

TABLE 2 SUMMARY OF RESULTS

WELLS NO. 12, 30, 32, CROWLEY OIL AND MINERAL COMPANY

Duration of tests, hours	6.0
Mean (total) i.h.p.	151.1
" " w.h.p.	25.14
" " a.h.p.	129.05
Total gallons of fluid per hour	6168.0
" barrels " " " "	146.87
" " " oil " "	16.17

WELL NO. 12

Weight of 1 gal. of fluid	8.5
Temperature of fluid	118.5
Per cent of salt water in fluid	87.2
" " " sand " "	1.3
" " " crude oil " "	11.5
Barrels of oil per hour	6.44
Specific gravity of oil	0.87
Total depth of well in feet	1705.00
Size of casing, inches	6.00
" " discharge line, inches	4.00

WELL NO. 30

Height above ground to which fluid was pumped, feet	17.5
Total length of vertical discharge line	1025.5
" " " " air line	992.58
Weight of 1 gal. of fluid	8.65
Temperature of fluid	120.2
Per cent of salt water in fluid	88.3
" " " sand " "	1.5
" " " crude oil " "	10.2
Barrels of oil per hour	4.83
Specific gravity	0.9
Total depth of well in feet	1920.00
Size of casing, inches	6.00
" " discharge line, inches	4.00

Height above ground to which fluid was pumped, feet	18.00
Total length of vertical discharge line	1516.3
Total length of vertical air line in well	1494.2

WELL NO. 32

Weight of 1 gal. of fluid, pounds	8.7
Temperature of fluid	114.5
Per cent salt water in fluid	86.9
" " sand " "	1.8
" " crude oil " "	11.3
Barrels of oil per hour	4.90
Specific gravity	0.9
Total depth of well, feet	1901.00
Size of casing, inches	6.00
" " discharge "	4.00
Height above ground to which fluid was pumped	18.5
Total length of vertical discharge line	1513.0
Total length of vertical air line in well	1493.0
Size of air lines in wells, inches	1.25
Barometer reading, inches of mercury	29.95
Dimensions of compressor, inches*	10x22x16x20
Number operated	1
Kind of fuel used†	Crude oil
Barrels of fuel used per hour	1.45
Price of 1 bbl. of oil at time of test, dollars	0.90
Cost in fuel of producing 1 bbl. of oil, dollars	0.074

*Type of compressor used, Rand Drill Co. Imperial Type X, duplex steam cylinders, compound or two stage, air cylinders.

†Type of boilers, oil well supply, portable contracted waste.

TEST NO. 3

MILL HILL NO. 2, MAMOU POWER COMPANY

31 This test was run in the same manner as those preceding except that the fluid field was ascertained by means of a two-foot rectangular weir placed between the earthern fluid and oil pits, the salt water bleeds of the former having been closed. The old system used was that illustrated in Fig. 3.

32 The depth of fluid over the crest of the weir was measured by means of the ordinary hook gage calibrated to read accurately in hundredths of a centimeter. The weir constant was previously determined by testing in the usual way, using a sample of the fluid as pumped from the well.

TABLE 3 SUMMARY OF RESULTS

WELL NO. 2, MAMOU POWER COMPANY

	Old System	New System
Duration of tests, hours	10.0	10.0
Mean i.h.p.	99.1	62.8
" w.h.p	9.85	13.36
" a.h.p	82.5	50.4
Gallons of fluid per second	0.694	0.849
" " " " hour	2499.6	3056.4
Barrels of fluid per hour	54.75	72.77
Weight of 1 gal. of fluid, pounds	8.72	8.75
Mean temperature of fluid, deg. fahr.	118.3	117.9
Percentage of salt water in fluid	87.7	86.1
" " sand " "	1.2	1.6
" " crude oil in fluid	11.1	12.3
Barrels of oil per hour	6.08	8.95
Specific gravity of oil	0.9	0.9
Barometer reading, inches of mercury	29.94	29.93
Weir constant	24.39	24.39
Pumping constant	97.1	202.9
Total depth of well in feet	1901.0	1901.0
Size of casing, inches	6.0	6.0
Height above ground to which fluid was pumped, feet	3.33	3.33
Size of discharge line used, inches	4.0	4.0
Size of air line in well, inches		1.25
Total length of vertical discharge line	1500.0	1500.0
Total length of air line in well	1489.5	1489.5
Dimensions of compressor, inches*	7½x18x16x16	7½x18x16x16
Number operated	1	1
Kind of fuel used†	Crude oil	Crude oil
Gallons of fuel used per hour	44.22	30.53
Barrels of fuel " " "	1.05	0.727
Price of 1 bbl. of oil at time of test, dollars	0.85	0.85
Cost in fuel of producing 1 bbl. of fluid, dollars	0.0163	0.0085
Cost in fuel of producing 1 bbl. of crude oil, dollars	0.128	0.069

*Type of compressor used, Hall Steam Pump Co., Duplex steam cylinders, compound air cylinders, Plain "D" valves on steam end, poppet valves on air end.

†Type of boiler, 72″x18′ horizontal return tubular, manufactured by the Lockout Boiler Co.

CONCLUSION

33 A careful examination of the tests brings out several points that may require explanation.

34 The loss of air pressure by friction in the small 1¼-in. air line in the well, to which the footpiece of the new system was attached,

was approximately determined as follows: Pipe connections were made at the well top, so that by the manipulation of various valves, the air from the main line could be sent either through the $1\frac{1}{4}$-in. air line or into the space between the well casing and the discharge line. By noting the pressure gage readings in each instance, the friction loss (assuming that there is no loss by friction when air is forced between casing and discharge) is represented by the difference in the readings. Corrections were made, of course, for that part of the discharge line below the footpiece.

35 It was impossible to obtain the actual friction loss in said $1\frac{1}{4}$-in. line by other means more accurate than those employed. While some little error may be involved in assuming no friction loss in the one instance, a comparison of the loss thus obtained with the theoretical loss is quite favorable, the former loss being the greater.

36 Reference to Table 3 will show that the working submergence of the new system is less than that of the old, in spite of the fact that there is the same amount of pipe in the well in each case. This is due to the additional drop in pumping head caused by the increase of fluid yield. All calculations of submergence and pumping head were made from the observed air pressures after correcting for friction losses, etc. The mean of these calculations was verified as far as possible by actual measurement. This was done by shutting down the compressor after the well had been in steady operation for several hours and pulling the discharge line. The point at which the fluid stood, while the well was being pumped, was plainly defined on the pipe. The time required after shutting down the compressor to pull the first "triple" from the well was a fraction less than two minutes. Comparison of the actual pumping head and submergence thus obtained with those obtained by calculations from the pressure gage readings was in each case very close, a difference of 10 ft. 2 in. being the maximum.

37 Acknowledgment of valuable aid during tests is hereby made to the following who checked the writer in his various observations: On Well No. 32, to Mr. B. Brand, of the Crowley Oil and Mineral Co.; on Wells No. 12, 30 and 32, to Mr. Brand, Mr. J. Murphree and Mr. S. Bolin, of the Crowley Oil and Mineral Co.; on Well No. 2 of the Mamou Power Co., to Mr. J. A. Sonet of that company and his able assistants; and especially is the writer grateful to Mr. J. W. Smith for courtesies extended during the former's sojourn on the field.

APPENDIX

TABLE 1 TESTS OF WELL NO. 32

CROWLEY OIL AND MINERAL CO., EVANGELINE, LA.

Old System, November 4, 1907

Number	Time	Cu. Ft. of Free Air per Minute (Displacement)	Volumetric per Cent Efficiency	Temperature of Air Degrees Fahr.	Cu. Ft. of Free Air per Minute (Actual)	Fluid Level in Tank	Gallons per Minute	Cu. Ft. of Fluid per Minute	Ratio	Air Pressures: Discharge	Air Pressures: Intercooler	Air Pressures: At Well	Pumping Head	I. H. P.	W. H. P.	A. H. P.	R. P. M.	Submergence in Feet	Submergence per Cent	Pumping Efficiency per Cent
1	1:15	632.16	92.0	86.3	555.75	1 ft. 8$\frac{3}{4}$ in.	32.56	4.35	127.7	155.0	60	150.0	1167.0	118.3	10.03	103.37	72	346.5	22.8	9.7
2	1:45	623.38	91.5	86.3	545.06	....	32.56	4.35	125.2	157.2	60	153.5	1159.82	119.1	9.98	103.6	71	353.58	23.2	9.6
3	2:15	632.16	92.0	86.3	555.75	....	32.56	4.35	127.7	155.1	60	150.0	1167.0	118.3	10.03	103.4	72	346.5	22.8	9.7
4	2:45	632.16	92.0	86.3	555.75	....	32.56	4.35	127.7	157.4	60	149.0	1169.3	118.2	10.00	102.8	72	344.19	22.6	9.8
5	3:15	667.28	90.0	86.3	573.83	....	32.56	4.35	131.9	155.0	62	152.0	1162.7	123.4	9.99	107.3	76	350.82	23.1	9.3
6	3:45	658.50	91.0	86.0	571.79	....	32.56	4.35	131.5	166.3	60	150.0	1167.0	121.2	10.03	105.4	75	346.5	22.8	9.6
7	4:15	693.62	91.0	86.0	603.51	....	32.56	4.35	138.6	166.0	61	155.0	1155.45	130.5	9.92	113.5	79	358.05	23.6	8.8
8	4:45	667.28	90.0	86.3	573.83	....		4.35	131.9	166.0	60	155.5	1054.35	135.5	9.92	117.8	76	359.15	23.7	8.3
9	5:15	658.50	91.0	86.3	571.79	....	32.56	4.35	131.5	166.4	60	155.7	1053.84	123.6	9.92	107.5	75	359.66	23.7	9.2
10	5:45	693.62	91.0	86.0	603.51	....	32.56	4.35	138.6	155.0	62	156.4	1052.22	121.2	9.92	113.5	79	361.28	23.8	8.8
11	6:15	632.16	92.0	86.3	555.75	....	32.56	4.35	127.7	160.0	60	150.0	1167.0	118.3	10.03	103.4	72	346.5	22.8	9.7
12	6:45	649.72	91.6	85.7	569.34	4 ft. 11$\frac{1}{8}$ in.	32.56	4.35	130.6	163.0	60	155.0	1155.45	123.1	9.92	107.04	74	358.05	23.6	9.3

TABLE 1 TEST OF WELL No. 32—Continued

New System, November 6, 1907

Number	Time	Cu. Ft. of Free Air per Minute (Displacement)	Volumetric Per Cent Efficiency	Temperature of Air Degrees Fahr.	Cu. Ft. of Free Air per Minute (Actual)	Fluid Level in Tank	Gallons per Minute	Cu. Ft. of Fluid per Minute	Ratio	Air Pressures: Discharge	Air Pressures: Intercooler	Air Pressures: At Well	Pumping Head	I. H. P.	W. H. P.	A. H. P.	R. P. M.	Submergence in Feet	Submergence Per Cent	Pumping Efficiency Per Cent
1	12:00	448.4	92.0	82.0	395.8	1 ft. 6 in.	36.47	4.87	81.2	207	77	202	1076.5	91.5	10.3	79.6	76	416.5	27.9	13.0
2	12:30	442.5	91.5	82.0	388.4	....	36.47	4.87	79.8	207	77	202	1076.5	89.8	10.3	78.1	75	416.5	27.9	13.2
3	1:00	436.6	90.0	82.0	377.01	....	36.47	4.87	77.5	205	77	200	1081.1	86.7	10.4	75.4	74	411.19	27.6	13.8
4	1:30	436.6	90.0	82.0	377.01	....	36.47	4.87	77.5	205	77	200	1081.1	86.7	10.4	75.4	74	411.19	27.6	13.8
5	2:00	442.5	91.5	81.3	388.9	....	36.47	4.87	79.9	205	77	200	1081.1	89.5	10.4	77.8	75	411.19	27.6	13.3
6	2:30	442.5	91.5	81.5	388.8	....	36.47	4.87	79.9	205	77	200	1081.1	89.4	10.4	77.7	75	411.19	27.6	13.3
7	3:00	448.4	92.0	81.6	396.1	....	36.47	4.87	81.4	210	77	205	1069.6	92.5	10.3	80.4	76	423.4	28.4	12.8
8	3:30	442.5	91.5	81.2	389.1	....	36.47	4.87	80.0	207	77	202	1076.5	89.9	10.3	78.7	75	416.5	27.9	13.2
9	4:00	442.5	91.5	81.3	388.9	....	36.47	4.87	79.9	210	77	205	1069.6	90.7	10.3	78.9	75	423.4	28.4	13.1
10	4:30	436.6	90.5	81.0	379.7	....	36.47	4.87	77.8	205	77	200	1081.1	87.3	10.4	75.9	74	411.9	27.6	13.7
11	5:00	436.6	91.2	81.0	382.7	....	36.47	4.87	78.6	205	77	200	1081.1	87.9	10.4	76.5	74	411.9	27.6	13.6
12	5:30	442.5	90.2	80.5	383.9	....	36.47	4.87	78.1	205	77	200	1081.1	88.5	10.4	76.8	75	411.9	27.6	13.5
13	6:00	442.5	91.0	80.5	387.4	5 ft. 1¼ in.	36.47	4.87	79.5	205	77	200	1081.1	89.1	10.4	77.5	75	411.9	27.6	13.4

TABLE 2 TEST OF WELLS NO. 12, 30, AND 32

CROWLEY OIL AND MINERAL CO., NOVEMBER 13, 1907

NEW SYSTEM INSTALLED IN EACH

Number	Time	Cu. Ft. of Free Air Per Minute (Displacement)	Volumetric Efficiency (Mean)	Temperature of Intake Air, Degrees Fahr.	Cu. Ft. of Free Air Per Minute (Actual)	Gallons per Minute			Total Gallons Per Minute	Cu. Ft. of Fluid Per Minute	Ratio	Air Pressures					Gallons Per Minute Per 100 Cu. Ft. of Free Air	I. H. P.	W. H. P.			Total W. H. P.	R. P. M.	A. H. P.	Per Cent Submergence			Pumping Heads			Pumping Efficiency
						No. 12	No. 30	No. 32				Discharge	Intercooler	At Well No. 12	At Well No. 30	At Well No. 32			No. 12	No. 30	No. 32				No. 12	No. 30	No. 32	No. 12	No. 30	No. 32	
1	11:00	719.9	....	76.5	628.02	39.2	33.2	30.4	102.8	13.74	45.7	217	65	128	202	205	16.4	155.7	7.1	9.4	8.6	25.1	82	132.3	25.9	28.0	28.4	696.9	1077.7	1069.6	18.9
2	11:30	719.9	....	76.5	628.02	39.2	33.2	30.4	102.8	13.74	45.7	215	65	128	205	202	16.4	155.1	7.1	9.3	8.65	25.05	82	131.9	25.9	28.5	27.9	696.9	1070.8	1076.5	19.0
3	12:00	710.2	....	76.7	619.3	39.2	33.2	30.4	102.8	13.74	45.1	215	65	128	205	200	16.6	152.9	7.1	9.3	8.7	25.1	81	129.9	25.9	28.5	27.6	696.9	1070.8	1081.1	19.3
4	12:30	702.4	....	76.7	612.3	39.2	33.2	30.4	102.8	13.74	44.5	215	65	128	202	200	16.8	151.2	7.1	9.4	8.7	25.2	80	128.5	25.9	28.0	27.6	696.9	1077.7	1081.1	19.5
5	1:00	684.8	....	77.0	584.04	39.2	33.2	30.4	102.8	13.74	42.5	215	65	128	202	202	17.6	144.3	7.1	9.4	8.65	25.15	78	122.5	25.9	28.0	27.9	696.9	1077.7	1076.5	20.4
6	1:30	693.6	....	77.0	604.5	39.2	33.2	30.4	102.8	13.74	43.9	215	65	133	202	202	17.0	149.3	6.9	9.4	8.65	24.95	79	126.9	26.9	28.0	27.9	685.5	1077.7	1076.5	19.7
7	2:00	719.9	90	77.0	627.4	39.2	33.2	30.4	102.8	13.74	45.6	217	65	128	205	205	16.4	155.6	7.1	9.3	8.6	25.0	82	132.3	25.9	28.5	28.4	696.9	1070.8	1069.6	18.9
8	2:30	693.6	....	76.5	605.7	39.2	33.2	30.4	102.8	13.74	44.1	215	65	128	202	200	16.9	149.6	7.1	9.4	8.7	25.1	79	127.0	25.9	28.0	27.6	696.9	1077.7	1081.1	19.7
9	3:00	710.2	....	76.5	619.7	39.2	33.2	30.4	102.8	13.74	45.1	215	65	128	202	200	16.6	153.1	7.1	9.4	8.7	25.2	81	130.0	25.9	28.0	27.6	696.9	1077.7	1081.1	19.3
10	3:30	702.4	....	76.0	613.3	39.2	33.2	30.4	102.8	13.74	44.6	215	65	123	202	202	16.5	151.5	7.2	9.4	8.65	25.25	80	128.7	24.5	28.0	27.9	708.5	1077.7	1076.5	19.5
11	4:00	702.4	....	76.0	613.3	39.2	33.2	30.4	102.8	13.74	44.6	215	65	128	205	205	16.8	151.5	7.2	9.3	8.65	25.1	80	128.7	25.9	28.5	28.4	696.9	1070.8	1069.6	19.5
12	4:30	710.2	....	75.5	620.7	39.2	33.2	30.4	102.8	13.74	45.2	215	65	128	202	202	16.6	153.3	7.2	9.4	8.6	25.25	81	130.3	25.9	28.0	27.9	696.9	1077.7	1076.5	19.3
13	5:00	702.4	....	75.5	613.9	39.2	33.2	30.4	102.8	13.74	44.7	215	65	128	202	202	16.8	151.5	7.2	9.4	8.65	25.25	80	128.7	25.9	28.0	27.9	696.9	1077.7	1076.5	19.5

TABLE 3 TEST OF HILL NO. 2

MAMOU POWER CO., EVANGELINE, LA.

Old System, February 27, 1908

Number	Time	Cu. Ft. of Free Air per Minute (Displacement)	Volumetric Efficiency	Temperature of Air Degrees Fahr.	Cu. Ft. of Free Air per Minute (Actual)	Depth of Fluid over Weir, Cm.	Gallons per Minute	Cu. Ft. of Fluid per Minute	Ratio	Air Pressures			Pumping Head	I. H. P.	W. H. P.	A. H. P.	R. P. M.	Submergence Feet	Submergence, per Cent	Pumping Efficiency per Cent
										Discharge	Intercooler	At Well								
1	7:45	413.6	85.2	75.1	342.46	1.71	41.7	5.57	61.5	260	80	252.5	916.72	91.8	10.1	75.3	88	583.28	38.8	13.4
2	8:45	441.8	84.7	77.5	362.04	1.72	41.95	5.61	64.5	260	80	252.5	916.72	93.3	10.2	75.3	94	583.28	38.8	13.5
3	9:45	498.2	85.0	77.8	409.51	1.71	41.7	5.57	73.4	255	80	247.4	866.14	108.9	9.6	89.4	106	633.86	42.3	10.7
4	10:45	470.0	85.0	78.2	386.01	1.70	41.46	5.54	68.5	255	80	247.4	866.14	98.8	9.5	81.5	100	633.86	42.3	11.6
5	11:45	526.4	86.1	78.7	436.53	1.72	41.95	5.61	77.9	255	80	247.4	866.14	115.7	9.6	94.5	112	633.86	42.3	10.2
6	12:45	462.2	85.3	78.8	380.52	1.71	41.7	5.57	69.1	255	80	247.4	866.14	101.2	9.6	82.3	98	633.86	42.3	11.7
7	1:45	470.0	84.5	81.3	381.55	1.71	41.7	5.57	68.5	255	80	247.4	866.14	101.5	9.6	81.7	100	633.86	42.3	11.7
8	2:45	432.4	84.5	81.6	350.83	1.71	41.7	5.57	62.9	260	82	253.0	915.57	95.5	10.1	77.5	92	584.43	38.9	13.0
9	3:45	441.8	84.7	77.5	362.04	1.71	41.7	5.57	64.9	260	82	252.5	916.72	93.3	10.1	76.4	94	583.28	38.8	13.2
10	4:45	441.8	84.7	76.2	362.04	1.70	41.46	5.54	65.4	260	82	252.5	916.72	93.3	10.0	76.3	94	583.28	38.8	13.1
11	5:45	535.8	85.1	75.0	443.21	1.70	41.46	5.54	80.0	260	82	252.5	916.72	97.1	10.0	97.1	114	583.28	38.8	10.3

New System, March 3, 1908

1	7:20	282.0	86.3	72.3	237.80	2.09	50.98	6.81	34.9	220	80	213.5	996.32	59.7	13.5	48.5	60	493.18	33.1	27.8
2	8:20	282.0	86.3	72.3	237.80	2.09	50.98	6.81	34.9	226	80	218.3	985.23	60.5	13.3	49.2	60	504.27	33.8	27.1
3	9:20	291.4	85.7	73.5	243.52	2.10	51.22	6.84	35.6	220	80	214.0	995.16	61.3	13.5	49.5	62	494.34	33.2	27.4
4	10:20	282.0	86.3	73.8	237.08	2.08	50.73	6.78	34.9	220	80	214.0	995.16	59.7	13.4	47.6	60	494.34	33.2	28.2
5	11:20	291.4	85.7	74.2	243.10	2.08	50.73	6.78	35.8	220	80	214.0	995.16	61.1	13.4	48.8	62	494.34	33.2	27.6
6	12:20	338.4	86.1	75.0	283.21	2.09	50.98	6.81	41.6	220	80	214.0	995.16	71.3	13.4	57.1	72	494.34	33.2	23.6
7	1:20	310.2	86.5	76.1	260.27	2.09	50.98	6.81	38.2	225	80	217.5	987.07	65.8	13.3	53.2	66	502.43	33.07	25.0
8	2:20	310.2	86.5	78.3	259.21	2.08	50.73	6.78	38.2	225	80	217.5	987.07	65.5	13.2	51.7	66	502.43	33.07	25.9
9	3:20	291.4	85.6	77.1	241.98	2.09	50.98	6.81	35.5	225	80	217.5	987.07	61.2	13.3	49.3	62	502.43	33.07	27.1
10	4:20	282.0	86.3	76.3	234.12	2.10	51.22	6.84	34.2	220	80	214.0	995.16	58.8	13.5	47.3	60	494.34	33.2	28.6
11	5:20	310.2	86.5	72.8	261.88	2.09	50.98	6.81	38.4	220	80	214.0	995.16	65.7	13.4	52.2	66	494.34	33.2	26.2

DISCUSSION

LIQUID TACHOMETERS

By Amasa Trowbridge, Published in The Journal for Mid-October

Mr. Sanford A. Moss. I have had some experience with liquid tachometers and quite agree with all that has been said about the excellence of this form of instrument for measuring speed. Personally, I believe that a liquid tachometer calibrated by some such means as that described in the paper is the only satisfactory form of speed-measuring instrument which we have.

2 I have frequently seen the attempt made to verify a liquid tachometer by measuring the revolutions with an ordinary revolution-counter and stop-watch, and comparing with the tachometer reading. I have found it a common impression that such calibration is necessary in order to be sure the instrument is in proper working order. It seems to me, however, that the only verification needed is to make sure that the instrument reads zero when stationary. Particular attention should be given to this point and a liquid tachometer should be so made as to be very readily set at zero. Some makes are inconvenient in this particular. If the instrument reads zero when stationary, and if the scale is originally correct, it seems to me certain that all other readings will be correct without verification by revolution-counter.

3 In the form of instrument described by Mr. Trowbridge, there is a horizontal shaft and a stuffing-box. In practical experience with this form of instrument, I have found it difficult to keep the stuffing-box absolutely tight and probably some of the troubles attributed to evaporation may have been due to a leaking stuffing-box. If the instrument can be conveniently stopped frequently to adjust the zero, a slight leakage will give no difficulty. To do this is often very inconvenient, however, and the instrument must be used without stopping for perhaps a day at a time. In such cases the necessity for resetting the zero is a very serious matter. A form of instrument with a vertical shaft has been proposed, in which this difficulty is obviated. I hope a precise instrument of this form will be made commercially.

THE ENGINEER AND THE PEOPLE

By Morris L. Cooke, Published in The Journal for Mid-October

ABSTRACT OF THE PAPER

Many present-day conditions, among them the broadening of human knowledge, and the generally recognized necessity for coöperation, will force the engineering profession and the individual engineer to take a more direct interest in affairs affecting the public. This will be especially true in matters involving engineering. A corresponding change is already in progress in other professions, notably in the medical profession. If engineering is to take full possession of the field which the public is willing it should occupy, more effort must be put forth along lines of purely public interest, and every opportunity be given the public to coöperate with the engineer. To execute this general policy the appointment is recommended of a standing committee to be known as The Committee on Relations with the Public.

DISCUSSION

Dr. Alex. C. Humphreys. I find myself very fully in accord with Mr. Cooke's proposition and arguments, and I might almost be willing to let my discussion consist simply of this expression of agreement; but by direct reference to certain parts of the paper, I may add emphasis to Mr. Cooke's main proposition—that this Society should in a definite way recognize and meet its responsibilities to the public.

2 As individuals our responsibility increases as our capacity for service increases: with increased power comes increased responsibility. As engineers, we must bear a definite responsibility by reason of our special training, not only as members of a profession but as citizens qualified along certain specific lines. And as individuals, this responsibility will vary in direction and measure according to our capacity to advise along certain well-defined lines.

3 Many of the questions most prominently before the public today, and receiving constant attention from our legislators, munici-

pal, state and national, are involved in the problems of industrial management, in connection with which the guidance of the qualified engineer, under proper selection, can be made available for the benefit of the people at large.

4 It is manifest that much of our law-making during the past few years has been conceived in ignorance and born of misinformation. Much of this misinformation has been furnished by doctrinaires; not a little of it by technically educated men who failed to recognize that competency in one line of engineering or industrial activity does not necessarily imply competency in all other lines. So the responsibility rests upon the engineer, not only to use his knowledge where it can be employed authoritatively for the public good, but modestly to withhold his advice unless his technical training has been adequately supplemented by practical experience.

5 Here come in the advantages accruing if this responsibility to the public is recognized by such an organization as ours, rather than if its recognition is confined to individuals. Advice offered by our Society, or by any other engineering society of established reputation, would be that which had stood the test of discussion and criticism by the membership at large or had been carefully canvassed by a competent committee, as suggested by Mr. Cooke.

6 The American Gas Institute, organized some three years ago through the amalgamation of a number of the more prominent associations of gas engineers, has two standing committees—with power to appoint sub-committees—which have general charge of all investigations and the procuring of papers for its conventions; these are the Technical Committee and the Public Relations Committee. That the problems of public relations are more definitely pressed upon the attention of the members of the Institute than upon the members of the A. S. M. E. is at once apparent, but a little thought will go far to convince the indifferent that a considerable number of our members are interested in vocations dependent upon a correct understanding by the public and its representatives of certain general principles of industrial management.

7 Mr. Cooke says (Par. 22), "It is no longer possible for either a profession or a craft to corner information and hold it for its own use." I contend that, if such an attempt is made, the layman, or public, will in all probability accept the false instead of the true, to the disadvantage of those interested in the profession or craft. This suggests as a motive, "Honesty is the best policy," but a right course taken from a selfish motive is better than a wrong course, and we may look hopefully for the development of higher motives later.

8 The engineers of this country individually, and still more so, collectively, are responsible as units of a self-governing people, to guide public opinion aright, wherever they are specifically qualified, and so to guide legislative and executive action. Perhaps we may be more inclined to recognize our responsibility, if we constantly bear in mind that, *as engineers,* we are not scientists, but that we are charged with the duty of practically applying the truths of science to the solution of the world's industrial problems.

9 This responsibility should be kept constantly before the students of our schools of engineering. Especially should this be a feature of the instruction in the departments of engineering practice; though opportunities for impressing upon students their duty as citizens are not confined to any one department.

Dr. Talcott Williams.[1] The suggestion in this paper on The Engineer and the People is the natural and fortunate product of the joint experience of the mechanical engineer and the journalist, of the lessons of the technical school and of the newspaper office. Mr. Cooke has had both; few have. Guided by this twin experience of the engineer and the newspaper man, he has pointed out why the calling which has a more severe technical training than any other and gives this age, in the various work and achievement of engineering, its crowning difference from other ages, has less weight in public affairs and on public opinion than any other. Engineering creates modern life. Take away engineering, and we are what our predecessors were. Add engineering, and the modern world is.

2 Yet this creation pays less attention to the word of its creator than to any other factor in its daily being. What engineer here has not seen in some public work or design money wasted today, or waste made sure in the near future, for lack of engineering advice known to engineers? The contractor overrides the engineer. The builder gets the better of the designer. The politician controls the technician. The railroad from beginning to end is engineering. Can any man here feel that the engineer, as such, in all his various functions, has his fair share and say in the railroad? A reader of technical journals from my youth up, when I became a reporter, nothing amazed me more, after I had read with the keen interest of one who knew only enough to admire, of the brilliant skill with which some engineer had made the impossible, possible, than to go to report the "opening" and find everybody on hand, and sometimes, everybody's name on the work,

[1] Talcott Williams, LL.D., of Philadelphia.

save the one man who had made it famous, but had not made himself known. Somewhere at the back of the platform, if he was lucky enough to get there, strolling uneasily around unnoticed, was the man who had a right to say, "I am it." As Proverbs has it, when the poor wise man had "saved the city," no man "regarded his name." I may exaggerate, but I am sure there are men here who have felt the proud humility of skill which finds in the consciousness of work done a reward greater than any other.

3 The army engineer officer, it is true, rarely has to suffer this. He has his full share of the limelight. But there are several hundred civilian engineers working on government jobs, some of them men of great ability, as we who read behind and see through the official reports know, who have not the position, the recognition or the pay for which their work calls. Would it be possible for these men, some of them grown gray in government service, to stand where they do, if the calling of engineering had the public ear and the attention Mr. Cooke urges and proposes to secure? Is it not true that the engineer, oftener than any other highly-educated man, sees

> Art made tongue-tied by Authority,
> And Folly, doctor-like, controlling Skill.

4 The reason is simple. In every social system, a man or men, a class or a calling, will have weight, influence and authority in proportion to its access to the center and origin of authority and power. Let this center be the King, as in France for centuries, and the courtier will rule, every noble will seek Versailles, and it will be true, as Nicholas I of Russia said, when Victoria asked him who his greatest noble was, "The one I spoke to last." Let a class rule and men will sacrifice self-respect and become snobs to enter that class or to know its members, as has been true in England under an aristocracy. In a broad democracy, the men who have access to the mass are certain to have weight. Look at the weight of the lawyer, always reaching the public. When in New England men went to church, the minister counted. The "political machine" itself is but a way of organizing the mass vote.

5 The engineer in all this has the disadvantage of a silent profession. His calling is recent. Its work is not understood. Much is incomprehensible to the average man. How few men, not engineers, can even read with comprehension recent reports on the failures of two great bridges at Quebec and New York? The working of a proposed statute can be made clear to any man; the death-rate from disease any community can understand: while to read a strain sheet

calls for years of training. It is true of most engineering problems and their solution, that even the educated man, much less the mass of men, can understand only results. The engineer who secures these results, as I have already pointed out, too often fails to get credit. Failing to get credit, he fails to have weight with the community, which blunders and wanders for lack of his guidance.

6 The time of a good engineer is too valuable to civilization to be used up in mere personal agitation. There is besides something in the engineer's training which makes him an intellectual aristocrat; what he knows, he knows. He loathes personally putting himself forward. He it not made that way. Words are not his tools.

7 The practical result is that there is no class so able and so silent, none so visible in its work and so invisible in its personalities. There is today no body of men, knowing so much, which influences public opinion so little, none whose work educates the public, which rules us all, so little. Who of you does not know of engineering blunders and engineering wastes because the large public of voters and the small public of directors are ignorant of what has been done in engineering? Both are ignorant because your profession does less than any other to educate the public. Look at the work for public health done by doctors, for new laws by lawyers, by my own calling in awakening the public. The engineer will never stand where he should in the modern State, until he too discharges his duty at this point. The doctor has his societies, the lawyer, his associations. Are your societies doing their share? Neither doctor nor lawyer speaks individually, nor need the engineer; let local and national engineering societies speak.

8 Take the stationary engine. We all know that in this country it is insufficiently protected against injuring and maiming and killing those at work about it. You know the safeguards that should be imposed by law to keep the balls on a governor from slaying, for instance, or to make the work of the oiler safer. Some day you will face a fool law on these and other points of danger, hampering all your work as mechanical engineers. Why ought not your societies so guide and frame the laws we are sure to have, to make our engines and machines safer? A large concrete construction collapsed in Philadelphia not long ago, slaying helpless men, because a contractor found it easier to steal professional plans than to hire professional skill. Suppose on the heels of that disaster a Philadelphia Society of Engineers had spoken through the newspapers clearly, emphatically and authoritatively? Was this not as much their duty as for a medical society to deal with deaths from pestilence?

9 Each year our State legislatures have before them dubious legislation on engineering issues. Some is sentimental ignorance. Some is ignorant sentiment. Some is sheer "strike." Some is wise. Medical societies take up medical laws. Legal committees and associations educate the public on their subjects. Why should not state and city engineering societies have their committees on legislation? The newspapers will always gladly print this collective, authoritative opinion. They worry you now, individually, for half-baked verbal utterances, hastily given and inaccurately reported.

10 After the Iroquois theatre disaster, every American city tried to set its theatrical house in order. At that moment, the careful technical utterance of anybody speaking for your profession would have been heeded all over the country. If accidents in machines causing loss of life were reported upon by mechanical engineers in our cities, the public would soon "stop, look and listen" for this utterance of the mechanical engineering conscience of the community, as such collective opinion would soon come to be.

11 If this were done systematically, if failures in construction or in design in public work had lucid authoritative exposition from engineering societies, if legislation were followed, if expert remedies were proposed by engineers for known evils, the public would come to look to these engineering societies for advice and the entire status and position of the engineer would change, and he would have the weight he should have as the maker of our current civilization, because he would be doing his duty in educating the great public, our sovereign, yours and mine, our larger self.

Hon. George W. Guthrie.[1] There are many serious public evils of which the people are keenly conscious and which they would like to have remedied, but because for want of technical knowledge they cannot see a remedy, they hesitate about undertaking any agitation for relief.

2 Merely to point out these evils does not materially help the situation; if, however, men whose training peculiarly fits them to deal with these questions and whose character and abilities are such as to command the confidence of the people, would point out both the evil and the remedy so that the people could understand what was needed, how to do it, and what it may cost, I believe progress would be more sure and rapid.

[1] Hon. George W. Guthrie, Mayor of Pittsburgh.

3 I know it is much to ask, but the reward would be the consciousness of a great public service and the relief of the people from remediable evils from which they suffer unnecessarily.

Mr. Fred. W. Taylor. Mr. Cooke's paper is so new and advanced that at a first reading it is difficult to grasp the everyday practical importance of his ideas. And the question which most of us will ask is, just what are we to do as a society toward coöperating with the public that we are not now doing as individual engineers? For after all we are now engaged in our daily work in coöperating either with individual members of the public or with the official representatives of the public.

2 It would seem on second thought that there must be a large range of subjects in which the Society either through committees or through a debating section, or through its employees (the Secretary and his executive staff) can coöperate with the public in a manner which would be entirely impossible for us as individual engineers.

3 Mechanical engineering problems are constantly recurring in the management and development of our cities, for example, which if not identical are yet similar. And it is to our Society, through its appropriate committees, that public officials should properly look for the standards, both mechanical and in method of procedure, which they should use in the solution of these problems.

4 The standards recommended by the committees of our Society should have (and in fact have had) a weight and influence far beyond that of any individual engineer, however eminent. One of several illustrations of this will be found in the standard method of making boiler tests recommended by our committee, which has been for several years the standard practically accepted throughout this country, and is likely to remain so.

5 It should take but a few years of active help and coöperation with the public for us to become the accepted authority to which both the legislative and administrative branches of our municipal, state, and national governments would turn both for general advice in framing legislation, drawing specifications, etc., and in the selection of engineers to carry out our public works.

6 As we all know, our most able and public-spirited Secretary has gained the complete confidence of the Administration at Washington by the efficient manner in which he helped the President in making a success of the White House Conference on the Conservation of our National Resources.

7 But few of our members, however, have heard of another instance in which our Society has been of great help to the Administration. Mr. Rice, this summer, and on very short notice, at the request of Dr. Rowe, chairman of the Delegation of the U. S. to the Pan-American Scientific Congress, secured 16 papers, some of them written by the most prominent engineers in their specialties, in this country, which are to be read at the First Pan-American Scientific Congress in Santiago, Chile. These papers should be of the greatest interest to our neighbors in South America, and should materially help in promoting friendly relations with them, and incidentally should direct their attention toward American engineers, and our standards and methods.

8 Das Verein Deutscher Ingenieure, certainly the largest engineering society in the world, and in many respects the most successful, has established perhaps more intimate and useful relations with the people and the government than any other engineering association.

9 Their committee on education, for example, has proved itself of so great practical value to the German government and to the engineering and technical schools, that no important step in this educational field is taken without obtaining their advice.

10 Our society has as yet appointed no committee on engineering education, although we have recently named two members on the Joint Committee for the Promotion of Engineering Education, appointed by the four large engineering societies and the American Society for the Promotion of Engineering Education.

11 Mr. Cooke's paper presents a large and almost unoccupied field of usefulness for our Society, and I trust that we may not be slow in acting upon his suggestions.

Dr. Arthur T. Hadley.[1] I have read this paper with great interest. I believe that the engineering profession will not reach the highest position of influence which lies open to it until it has appreciated more fully than it now does the lines of opportunity indicated therein.

Mr. Frank Miles Day.[2] This paper is significant of a broadening conception of the duties of the professional man, which is in itself but a part of the broadening conception of the duty of every man. At last, though still dimly, we are beginning to see that the welfare of all is

[1] Arthur T. Hadley, LL.D., President of Yale University.

[2] Mr. Frank Miles Day, Architect, Philadelphia, Pa., lecturer on architecture at Harvard University.

of deeper concern than the welfare of the individual, and as a part of this vision, it follows that the professional society at last apprehends that it owes a duty to the public quite as much as to its members.

2 I can hope to throw only a side light on the subject which Mr. Cooke has so suggestively illuminated, and that light, if I am able to throw it out at all, must come from my own profession—architecture.

3 The architect's work being so much in the eye of the public, the fact that the individual practitioner has a distinct duty to the public has long been recognized, and of late years the duty of organizations of architects throughout the world to the public has been increasingly recognized; indeed the discussions of the great parliament of architects, the International Congress, are more largely devoted to questions of public utility than of the welfare of the profession.

4 Judging from the experiences of a sister society, the American Institute of Architects, there is a field of great utility awaiting the efforts of The American Society of Mechanical Engineers. The Institute, though it has occupied the field by no means as fully as might have been desired, has found many opportunities for service to the public. The movement for civic improvement which has made such strides in America has been notably fostered by the Institute and its members. In many of the larger cities, the local chapter of the Institute has taken the initiative in such matters and many civic improvements growing out of such initiative are now being seriously studied or are in course of execution.

5 Among these is the Commission for the Improvement of Boston, established at the instance of the Boston Society of Architects, and now doing serious work upon a most extensive scheme. This Commission has before it projects which for two years or more have received most careful study by the Society and which are presented in the form of admirable drawings and descriptions.

6 In Cleveland, Ohio, the local chapter of the Institute gave the impetus that resulted in the appointment of an expert commission whose splendid plan for the grouping of public and semi-public buildings is now being carried into execution.

7 At the Capitol of the nation, the Institute itself was instrumental in securing the appointment of an expert commission whose members served without remuneration, and formulated plans so convincing by the authority of their excellence, that Washington already seems a different city by virtue of work carried out in accordance with them.

8 Although in these and many other instances, the Institute has done notable work in assisting municipalities to solve difficult problems

worthily, there is still a strong feeling among many of its members that the Institute is not closely enough in touch with the general public.

9 To improve this relation, the last convention directed that a Committee on Relations with the Public be appointed. Although there has not as yet been time for extended work on the part of this committee, its program includes:

- *a* An attempt to secure through the lay press, more worthy criticism of important buildings as they are from time to time completed, more adequate reports of the annual convention of the Institute, and more intelligent notices of architectural exhibitions.
- *b* A series of magazine articles on the status and duties of the architect, on good and bad professional practice, on the evils of ill-regulated competitions and on kindred subjects.
- *c* An effort not only to interpret the aims and ideals of the profession to the public, but to assist the public n the conception that architecture is one of the fine arts.

10 It is hoped that something may also be done to impress upon the public the need of sound training for the architect, something that may help to deter the half-prepared or wholly unprepared youth from attempting a career that requires the fullest preparation, a preparation not merely of a highly special and technical character but a foundation of broad general culture equivalent to that indicated by the degree of Bachelor of Arts.

11 The Institute, from time to time, shows its interest in matters of import to the public by holding open meetings at which such subjects are discussed, or at which it evidences its interest in the sister arts of painting and sculpture by giving exhibitions of them. For example, at the approaching convention of the Institute, the matter of chief public interest will be a splendid collection of the works of Augustus St. Gaudens to be exhibited at the Corcoran Gallery under the auspices of the Institute, at which time the Secretary of State and the French, English and other ambassadors will deliver eulogies of St. Gaudens and his work.

12 Upon one matter which Mr. Cooke has approached I would say a few words. The relation of technical, artistic and learned societies to each other is an important one. At present, these relations are by no means as close or profitable as they might be. To speak only of mechanical engineers and architects: it is fair to say that owing to the

necessity for the services of engineers of high attainment in designing the mechanical and electrical equipment of modern buildings, architects and engineers have been brought into much closer touch than formerly, and to their mutual advantage. But this is an individual affair. Cannot the architects as a body, through their Institute, be of service to the engineers as a body through their Society and conversely cannot the Society be of use to the Institute?

13 With this significant question, I leave the discussion, again thanking Mr. Cooke for his most illuminating paper.

Mr. H. F. J. Porter. Every member of this Society presumably belongs to one or the other of the two classes, *the employed* and *the employer*, which compose "the people" to which Mr. Cooke refers, and if he is as progressive as all of our members are supposed to be he should desire to see the conditions which affect each of these classes, as well as their relations to each other, improved.

2 That need for such improvements exists is evident, on the one hand from the contents of papers presented to this Society and to the "Societies for the Promotion of," respectively, "Technical" and "Industrial" Education, on the subjects of shop organization and management, and on the other hand from the recent establishment of courses of instruction in those same subjects in the representative technical schools and colleges throughout the country. That these improvements are expected to be brought about largely through the instrumentality of the members of this Society is indicated by the fact that many of the latter are in great demand as specialists in reorganizing shops and in improving their systems of management and are being appointed on the staffs of lecturers in these schools and colleges.

3 To no man is presented a greater opportunity to wield a permanent influence over his fellow men than to the employer; for he directs the thoughts and actions of his employees through the major portion of their waking hours, and according to his use of that opportunity he may become a power to uplift or to degrade them and his obligation to his country as a citizen is thereby involved.

4 I have known an employer for whom, as he expressed it, "the best was none too good," whose plant was in every respect a model one and who was still soliciting from his employees and from outside specialists suggestions for its further betterment. His work rooms were not only well lighted and ventilated, but the air was filtered and maintained at a constant temperature by regulating apparatus, summer and winter, and the other sanitary appliances were equally modern. A wash room on each floor was supplied with hot and cold

water, soap, towels and clothes lockers. A simple and wholesome lunch was furnished at cost amid attractive surroundings. Technical and popular literature was supplied with the privilege of taking it home. A beneficial organization fostered by the company supplied a doctor whose duty was to prevent sickness and keep every one in efficient working condition. Long-service pensions tended towards permanency of occupation. Many of the employees held stock in the enterprise which was paying handsome dividends. The employees were receiving the highest wages paid in the industry. They were of the highest grade and were giving their best and willing service.

5 Another employer, the conditions of whose shop as regards comfort, health and working facilities, were so wretched, and the treatment of whose cheap (?) help was so bad that no self-respecting man would submit to them, repeatedly refused to supply any washing accommodations in his plant, until the Molders Union obtained the passage of a law by the State Legislature requiring Foundries to supply wash rooms and the State Commissioner of Labor forced him to act. He then complied with the letter of the law by installing some sinks in a dark cellar of an adjoining building, so inconvenient of access by the molders that they would never go there, and then gloated over his shrewdness in circumventing their plans. He was losing money every month and finally conceived the idea that all he needed to make the place pay was to install a cost system. He stated that there would be no difficulty in introducing any system or methods in his organization as "he had his men thoroughly cowed."

6 It does not require a very vivid imagination to appreciate the difference in the effects produced by the methods of these two men on their organizations and on the communities in which their shops were respectively located.

7 These are two extreme types of employer and there are many intermediate ones, but there is a large class of employers not generally recognized by that name, and yet who are a potent element in affecting the relations between capital and labor in which "the people" are so vitally interested. This is the rich man, oftentimes a banker, who has acquired the controlling interest in a successful enterprise by advancing money to it on account of some friend who has become involved in it. He is an employer by accident. He takes no further interest in the affairs of the enterprise than to get a return on his investment. He puts in charge as manager his friend, who possibly through his ignorance of the principles of management was the original cause of its lack of success. His constant injunction

is to "keep down expenses." The manager gets financial assistance in driblets, for the absentee employer is enjoying himself abroad or on his yacht or is engrossed with his other pleasures and does not wish to be bothered. The low wages, the lapsed pay-days, the frequent lay-offs due to lack of supplies, the unpaid bills for material purchased, are not only the far-reaching causes of inconvenience but sometimes of absolute misery. Such employers consider too lightly the social and economic effect of their methods on "the people."

8 There is little wonder that the labor unions have gained adherents to their ranks, and have found plenty of incentive to use extreme methods in fighting to secure better conditions for their members. If there were no such employers there would be no reason for unions of the type that now exist. Many employers have yet to learn how dependent they are for the success of their ventures, upon their treatment of their employees, which involves their families and the community about them.

9 Your members who are engaged in the work of reörganizing shops will witness that a large proportion of failures in industrial enterprises are due to arbitrary methods of management. Owing to internal improvements in industrial establishments brought about by competition and the general advance of the times, changes in the methods of management of the past have become necessary. These changes are directed away from the centralized or one-man source of authority towards distributed power or committee management. The executives of our largest industrial enterprises are urging their employees to become stockholders, and thus part owners, having a voice in their policy of management.

10 This is a repetition in the field of industrial government of what has taken place in national and religious government, viz: a change from the monarchic or autocratic rule, which was synonymous with tyranny and oppression, to more liberal methods as exemplified in the democratic form of government. This change is not occurring without a struggle. There are still plenty of members of the old school who believe in a ruling class and a subject class, and that the latter have no rights not allowed them by the former. But the overwhelming force of the tide of democracy which we have recently seen sweep away the old order of things successively in Japan, Russia, Turkey, Persia, and China, is making its inevitable inroads in industry to the financial and social betterment of everybody involved. Even children are being taught self-government in their "School Cities," the George Junior Republic and the juvenile courts, and the "honor system" has come to stay in the colleges.

11 Realizing the far-reaching effect upon the industrial future of the country of the failure of the employer to realize the obligations which his privileges entail, efforts have been recently made, by those engaged in the work of shop reörganization, to establish a platform from which they could present their experiences that others might profit from them. Until the present time these efforts have seemed to be premature.

12 Now that our Society is enlarging its scope and offering opportunities for the establishment of sections, to the membership of which others than those qualified as engineers are eligible, it seems to me that the opportunity is here presented for managers and those interested in management to get together for the interchange of views and the discussion of those questions which have so important a bearing on the industries of this country, and therefore upon "the people" at large who are directly affected by them.

Mr. Arthur L. Church.[1] In my invitation to discuss this paper reference was made to the methods by which the University of Pennsylvania keeps itself before the public in order that the public may take an intelligent interest in it. Special reference was made to the publicity given the dedicatory exercises of its new engineering building.

2 The primary object of those in charge of the ceremonies was to dedicate the building in a manner befitting the dignity of the University and the importance of the event. Preparations were begun nearly six months in advance. The Provost of the University appointed a committee, with the head of the bureau of publicity of the University as its secretary. This committee, having the power to add to its own number, selected members from the trustees and engineering graduates from 1874 to 1901. These were divided into sub-committees on invitations, exercises, reception, publicity, finance, and dinner. Communications were established between this general committee and representatives from each graduated class of the University. The cost of the day's exercises and entertainment was about $5000, which was raised by the finance committee, chiefly among graduates of the engineering courses and engineering establishments in the vicinity of Philadelphia. The publicity given the event in the daily papers was chiefly due to the secretary of the general committee, Mr. George E. Nitzsche, and that given by the technical press to Dr. Henry W. Spangler and Dr. Edgar Marburg.

[1] Mr. Arthur L. Church, of Philadelphia.

3 About 23,000 invitations were issued, and representatives were present from institutions of learning, technical societies, and foreign, national, state and city governments. Degrees were conferred upon distinguished engineers; an address was delivered by Provost Harrison and by Dr. Alexander C. Humphreys for civil engineering, and Dr. Frederick W. Taylor for mechanical engineering; 2000 guests were entertained at a luncheon and 250 at a dinner, at which speeches were made by well-known professional men.

4 I heartily agree with Mr. Cooke's suggestion that technical societies should take an active and altruistic interest in questions affecting the public weal. This has been done in many instances by the Franklin Institute of Philadelphia and I believe it accounts in some measure for the hold which that institution has on the public and the interest which the public takes in its welfare.

Prof. A. W. Moseley. It must be admitted that the greater part of the work done by the mechanical engineer is of a kind that is unseen, unknown and unappreciated by the general public. Civil, architectural, naval, and certain other great divisions of engineering are more fortunate than we in this respect. It is true that an occasional pumping or power station, or locomotive, or "Machinery Hall" attracts general attention, but so many of our structural activities are confined to dark basements, narrow passages, and crowded shops and factories that they are known only to those who are brought into contact with them by their daily occupations.

2 It is fortunate that industrial engineering, so-called, is largely a problem of the mechanical engineer and is receiving well deserved attention from him. An intelligent and unselfish meeting of his opportunities in this field will bring him before the public in a more evidently useful and generally prominent light than ever before. For instance (and this is one of the problems of the industrial engineer), it is impossible to over-estimate the good that would be brought about were this Society, as a Society, to take a stand for the universal introduction of safety appliances and were every member to urge such adoption in all instances met in his practice.

3 But there is the æsthetic side as well as the ethical. Do we mechanical engineers give enough weight to the element of beauty in our designs of machines and in our layouts? The following quotation is from Dr. Waddell's De Pontibus: "In all structural work the subject of æsthetics must be duly considered: and all designs are to be made in harmony with the principles thereof, to as great an extent as

the money available for the work will permit or the environment of the structure calls for." This quotation is given because it is so well expressed and not because it is believed to be necessary to turn to another branch of engineering for such a statement. "Money available" and "environment," these are the sticking points. But more money is being made available, and with it, better environment; and the opportunities of the mechanical engineer to devote serious attention to æsthetic features are increasing daily. Here, too, he will meet the public and the public will thank him.

Mr. James M. Dodge. I am convinced that the suggestions of the author have touched sympathetic chords in the minds of all of us. I believe every one realizes how much in connection with the subject has not occurred to him before in crystallized form. I personally feel as I have felt when after reading an able editorial I am prompted to say, "That is exactly what I thought," but if any one had asked me to tell exactly what I thought before I had read the editorial I would not have covered myself with glory. It is not necessary now to consider ways and means for putting Mr. Cooke's suggestions into force because I believe now that he has set the ball rolling, it will never stop, but rather be accelerated in its progress by the professions for all time to come.

Mr. Ambrose Swasey. The field of the engineer is already very broad, much broader than when I joined this Society as one of its charter members. But there are still broader fields ahead of us, and I think this paper contemplates our entering these larger fields of usefulness.

2 A few days ago I had a talk with Congressman Burton. As you know, he has for several years been Chairman of the Rivers and Harbors Committee, and is one of the able men in Congress. In speaking of the work of the engineer in connection with this conservation movement, he said, "By all means the engineer should be found in the front rank, for he is a most important factor in this splendid work which we are about to undertake, a work of which we have just reached the edge, and which will go on and on, increasing as the years progress."

3 What Mr. Cooke has said means a step in advance for this Society and for the engineers of this country. It means that we are going to pay more attention to public matters, not simply to our private interests, but to the good of the people as a whole. In this connection I wish to present the following resolution:

4 Resolved, that we recommend to the Council the appointment of a Professional Committee, to investigate, consider and report on the methods whereby the Society may more directly coöperate with the public on engineering matters, and on the general policy which should control such coöperation.

Mr. Charles Wallace Hunt. This resolution, which Mr. Swasey has proposed, is really broadening the work of the Society. It may become a national engineering and economic movement, which may develop later as a section of the Society. With that in view, I second the motion made by Mr. Swasey. [The resolution was also seconded by Mr. Fred. W. Taylor and unanimously adopted.—Editor.]

Prof. F. R. Hutton. It has been suggested, in pursuance of the recommendation of Mr. Cooke (Par. 6), that a Committee on Relations with the Public should be created, following the analogies of the other Standing Committees of the Society.

As this calls for an amendment to the Constitution, which it is not in order to present to this meeting, I will at this time only give notice of the purpose, pursuant to the provisions of the Constitution, to amend Article C45, at the Spring meeting of the Society, at which such amendment can come up for discussion.

Mr. Oberlin Smith. I agree in general with the views of Mr. Cooke and his idea of a standing committee upon Relations with the Public. It may be that such a committee might also act as a Committee upon a "Code of Ethics" a matter which other societies are taking up and which we certainly cannot afford to neglect.

2 It is true that engineers as a body live too much to themselves and for their work, and do not sufficiently affiliate with the public in general. Perhaps we are too busy and too modest to attend to anything but our own work, or to exploit ourselves before an admiring public. The present condition is partly our own fault, and I would here urge, as I have in an annual address upon previous occasion, the higher self-cultivation of all engineers, in whatever branch of the profession. It is much to be regretted that, with the exception of West Point and Annapolis, few of our colleges and still less our technical schools, pay enough attention to this matter. In furtherance of these ideas, would it not be a wise policy for this Society to urge upon the technical schools of our country the adoption of broader and more liberal schemes of education, especially during a student's earlier years, that he might be caught (and taught) young?

3 From another point of view the public at large are to blame for not more thoroughly cultivating and recognizing engineers as the men who are creating, developing and maintaining the whole fabric of modern civilization. Many of them are doing splendid work in musty offices and drafting rooms for very moderate salaries, while the men who are exploiting and financing this work (with much less education, and in many cases smaller brains) are getting the big salaries and enjoying the credit of developing great industries and inaugurating public works.

4 This public has not yet even learned, in many cases, the difference between the machinist who shapes the iron into a steam engine, or the engineman who oils and cleans it and watches it run, and the professional engineer who, with the necessary ability, education and experience, has designed it. Surely it is to be hoped that our nomenclature will be improved in this respect, that we either will drop the name of engineer or try in earnest to limit it to professional men, using other names for the entirely different lower grades just mentioned.

5 It is also sincerely to be hoped, and I think with a good chance of early realization, that professional engineers, with their carefully trained minds, their years of experience in administrative work and their logical habits of thought, may occupy more of the public places of our land. Knowing what our profession is and does, it seems remarkable that it is not more often represented in the halls of Congress, in the Cabinet and even in the White House.

The Author. The engineering profession may almost be said to accept the conception of its duty toward the public as outlined in this paper, since all the discussion before the Society, in the technical press and elsewhere, has apparently been favorable. Even those who place the highest value on the work of the engineer are willing to admit that he has failed in this public function. There is little therefore to be gained from further discussion. Carlyle has said that "The end of Life is an Action, not a Thought, though it were the noblest." This injunction comes with added weight to a profession that stands for action, not speculation.

2 It is not too much to expect that The American Society of Mechanical Engineers should lead in the work of transforming this thought into action. Already its committees are showing in their various plannings the quickening thrill of a broader vision. It is nevertheless true that the Society acting as a corporate entity can

be effective in this work only as the individual activities of its members make it possible and as it is held up to the work by what may be called the suggestive influence of individual members.

3 May there not be danger that our progress may be retarded by our holding back as a Society and as individual members in order to take part in some great work which is to benefit the public in a large way? Doubtless there are such undertakings ahead of us. But one small piece of engineering work of a purely public character done by an engineer or an association of engineers with the utmost efficiency and done at once will advance the whole program more than would the proposing of a dozen more ambitious schemes which might one by one die in the process of being discussed.

DEVELOPMENT OF THE HIGH SPEED MILLING CUTTER, WITH INSERTED BLADES, FOR HIGH POWERED MILLING MACHINES

By Wilfred Lewis and Wm. H. Taylor, Published in The Journal for Mid-November

ABSTRACT OF PAPER

The main point in the milling cutter here shown and described is the use of inserted helical blades of high speed steel, mounted in a steel holder to give a solid backing for the blades on the driving side, against which they are held by a soft metal filler on the opposite side, thus giving a uniform support for the cutter blade on both sides from end to end.

Another point is the form of groove adopted to give a slight curvature to the blade across its width, and thus favor the realization of a lip angle from the cutting side. Not only are the blades held more securely in position by the method adopted, but they are also more easily removed when damaged, and new blades can be easily inserted.

The cutting power of a milling cutter built up in this way appears to be beyond the capacity of any machine now on the market, and the endurance of the cutters, as far as experiments have been made, is phenomenal.

DISCUSSION

Mr. Fred J. Miller. Most of us are, of course, familiar with the fact that milling cutters were first used generally for producing forms otherwise difficult to produce at reasonable cost. Parts of small arms and similar things were thus produced as the next step in advance of filing them to the required form and dimensions. Cutting the teeth of gear wheels was one of the first if not the very earliest use of the milling cutter.

2 In all such work the form of the cutter and the ability to keep it near its original form until worn out were the chief considerations; as indeed they still are for many kinds of work. This, more than anything else, probably, has led to the almost universal use of the radial front face for the teeth of milling cutters; because only by

having radial front faces could the problems connected with forming cutters and maintaining their forms be sufficiently simplified to be at all practicable. This seems to have led to what may be called the traditional practice of making the front faces radial in all cutters —even in the plain, solid, spiral cutters whose only office is to remove metal from a plane surface and which can as well be made and sharpened if they have front rake as with radial surfaces for the front of the teeth.

3 Radial surfaced teeth can scarcely be said to cut. They push and jam the metal off. When heavy cuts are taken this jamming becomes a serious matter and front rake is almost a necessity. Even a little front rake is very advantageous when the mere removal of metal from a plane surface is the object sought and it seems likely that such rake will become as common for milling cutters used on such work as it now is for lathe and planer tools and for the same reason.

4 Referring now to the tables at the end of the paper, I would suggest that in the heading of the last column in each table the words "per minute" be added. The figures given in these columns really mean the horse power per cubic inch of metal removed per minute. I would suggest also that another column be added to these tables giving either the cubic inches of metal removed per minute per inch width of cut, or, the number of pounds of metal removed per minute per inch width of cut.

5 Comparisons of the efficiency of cutters can be made only upon their performance per unit width of cut. For example, I find that the maximum performance shown in Table 1 is, the removal of 1.82 lb. of cast iron per minute per inch width of cut; the cut in this case being 3 in. less than the length of the cutter. This is at the rate of 7 cu. in. of cast iron per minute per inch width of cut.

6 The maximum performance shown in Table 2 is the removal of 0.74 lb. of 30 point steel per minute per inch width of cut; or, 2.62 cu. in. per minute per inch width of cut. The cut and the cutter are, in this instance, the same width.

7 In Table 3 the maximum performance shown is the removal of 6.56 cu. in. of steel per minute per inch width of cut.

8 These figures enable us to compare the performances on cast iron with those on steel, which the figures given in the table do not; and they show also the performance of the cutter as distinguished from that of the machine which drove it. The width of the surface from which a given cutter can remove a given quantity of metal per

unit width of cut depends upon the machine which drives the cutter and supports the work.

9 The performance of the cutter is shown by the work it can do per unit of time per unit width of cut; the power and efficiency of the machine by the number of those units of width of cut for which it will stand up and do its work satisfactorily.

Mr. Oberlin Smith. I want to ask the authors of this paper what they found to be the best lubricants (or "coalicants") for cast-iron, for mild steel and for brass respectively, also the best angle of rake, that is the angle with the radial line, in lathe-work, etc., respectively for the three metals mentioned.

2 Changing the subject a little, I ask the membership in general if they have had any experience either with boring tools or milling-cutters made by inserting a set of blades into grooves in wooden patterns, and molding them so that they remain in the sand for the casting of a hub or body about them, the same being hollow to go on a boring-bar or having a shank of its own to insert in a milling-machine spindle. I had some experience years ago in making such tools of from three to nine inches in diameter of mushet steel, finished in a grinding-lathe. It is not practicable to use carbon steel, as heating it for hardening is apt to crack the iron hubs. No doubt this scheme has been tried by a good many people, but with what success?

3 Doubtless high-speed steel cutters could be cast in this way, provided the heat of the cast-iron would not anneal them too much. That is a point to ask Mr. Taylor or Mr. Lewis about, or any one who has found out anything about it. Is there any practical way of using high-speed cutters, and casting them into a hub of iron? It is obvious that a large-toothed cutter can be made more cheaply in this way than in any other, but we do not want the slow speeds of mushet steel.

Mr. Fred W. Taylor. The writers of this paper, as well as that of Mr. DeLeeuw, speak of the "lubricant" used upon the tool and Mr. Oberlin Smith has just spoken of the best "lubricant" to use on a tool. In taking a heavy cut with a tool, in fact in doing any metal cutting in which a chip runs continuously across the lip-surface of a tool (except in the case of a light finishing cut) is it possible to get any lubricant between the chip and the tool? In cutting steel the tool receives a pressure from the chip of about 180,000 lb. per square inch at the spot where the chip rubs upon it.

Is it possible to get any lubricant between two surfaces, one of which is forced against the other with a pressure of 180,000 lb. per square inch on an average, and in which one surface is continuously moving past the other at the rate, we will say, of 40, 50, 60 or 70 ft. a minute?

2 I think this is utterly impossible when the nose of a tool is buried in the steel as it is in taking a roughing cut. The word "lubricant" is a survival from the practice of pouring a light trickling stream of water or oil on a finishing tool from a small water can supported above the tool, the function of the water or oil being to produce a polishing or burnishing effect upon the work. Water was not used in this way to cool the tool and was confined to finishing tools. Doubtless under a light finishing or scraping cut at the last instant a small amount of water or oil does find its way between the tool and the work.

3 On heavy roughing cuts, it is impossible to get any lubricants between the chip and the tool surface. It is, however, possible and desirable, in almost all roughing cuts, to have either water or oil thrown upon the chip and the tool for the purpose of cooling them, since, as pointed out by the writer in his paper, On the Art of Cutting Metals, a tool cooled in this way can cut from 15 to 40 per cent faster than a tool running dry. Cold water is the best conductor of heat, better than any of the oils, therefore it is the best of the cheap cooling-mediums to throw onto a tool. The only object of putting soap in the water on heavy cuts, or of putting soda in the water, is to stop rusting on the machine or work when the water splashes over. Cold water is the proper thing to pour on a milling-machine of this type. It cools better than any other cheap material known, and the cooler it is the better. The use of soda in water, or the substitution of oil for water on roughing cuts, is merely to stop rusting.

Mr. A. L. Deleeuw. Mr. Taylor's remarks upon lubricants brings to mind an experience I had just about one year before the famous Taylor-White steel was brought out. High speed for tools was in the air, and I tried to get results which have since been accomplished in an entirely different way, by simply cooling the tool and the chip. Realizing that it was impossible to force a lubricant of any kind between the tool and the chip, and that at the same time forcing the lubricant somewhere else would not cool the cutting point of the tool sufficiently to keep it from burning out, I had a ring constructed and attached to the compressed air supply. The ring was provided with a

number of small holes focusing at a common center and so adjusted on the lathe, as to bring the focus of all these small streams of air some little distance from the tool point. The air expanded, forming a center of refrigeration easily determined by a thermometer or by the finger. By adjusting the ring in such way that the center of refrigeration coincided with the cutting point of the tool, it was possible—and that was a year before the high-speed steels were brought out—to turn cast iron which had been rejected on account of its hardness, at the rate of 168 ft. a minute, and I do not know how much faster, because the lathe would not pull it. It was even possible to run steel at the rate of 250 ft. a minute, and I do not know how much faster it might have been run, if the lathe had allowed it.

2 This brings out strongly the same point Mr. Taylor has made, that the lubricant simply cools the tool. There is no object in cooling the chip, but of course we cool the tool by also keeping the chip cool.

Mr. Oberlin Smith. I want to go the gentleman who has just spoken one better. Some years ago, before high-speed steels came up, I came to the conclusion that all that is wanted is to cool the tool. The coolest thing I could get was liquid air. Procuring a can containing 15 gal., and taking every precaution to keep it in a liquid condition, I rigged up on a lathe an ordinary two-quart can with a $\frac{1}{4}$ in. pipe and spigot, and filled it with liquid air. I covered it with flannels, and tried to get some of it on the tool, but it would not run. The reason of course was that it expanded so fast in the small pipe that as a gas it pushed the liquid back into the can and held it there. The pressure upon the atmosphere was so violent that it held against a head of several inches. I then put in a $\frac{3}{8}$-in. pipe, but it would not run. With a $\frac{1}{2}$-in. pipe it did run but of course my supply did not last very long.

2 I have not any accurate records of just what speeds were obtained, but I did get a great deal higher speed than with usual ordinary carbon steel. With a one-inch drill the speed could be doubled in cast-iron. The liquid did not get well down among the chips, but if it had been forced down even greater results might have been obtained. If liquid air were properly handled and forced against the tools it would probably be the best cooling-agent we could secure. This, however, would seem wholly impracticable on the score of expense. If it could be forced immediately to the machines it might be effective, but in the ordinary machine-shop we start and stop the tools frequently, and where the pipes would have to be kept

well insulated to keep the liquid from getting warm it doubtless would not be feasible.

3 I had thought of patenting the combination of liquid air with a lathe milling-machine, etc., but Mr. Taylor's high-speed steel came out and cooled my enthusiasm below the temperature of the air. I now hereby give the invention freely to the world—if I am the original inventor of it—because I do not know whether it is really good for anything, and it is too much trouble to find out.

4 It is an open question whether steel gets brittle at low temperatures and would become so if cooled by liquid air. The metal being cut, and the tool itself, would probably become heated enough, however, so that there would not be this effect.

Mr. A. B. Carhart. The subject of lubricants may be a little apart from the main purpose of the paper, but the subject should not be allowed to drop where it is, after the remarks of Mr. Taylor. Why have great advantages been claimed for many years for lard oil and its compounds for lubrication in milling machine operations? The advantages of kerosene mixtures are recognized for cutting aluminum bronze castings and such metals. The greater conductivity of the lighter oil is easily recognized, but is there no other reasonable explanation of the predilection in favor of kerosene over the other oils; and aside from the rusting tendencies of clear water are there no reasons why mixtures of water with various skim milk compounds offered as substitutes for lard oil have any real value? If there are no advantages in oil other than its non-corrosive qualities, why is it that so much of the cutting oil on the market is so strongly corrosive of the machine tool members?

Prof. R. T. Stewart. In regard to lubrication under high pressures, there are industries in which that is effective. For example, in the cold-drawing of seamless steel tubes, if you attempted to draw steel tubes without lubrication, the effort would be futile. If you want a reduction in cross-section of say 5 to 10 per cent, you may use one lubricant successfully; but if you wish to get a reduction in cross-section of say 25 or 30 per cent, by cold drawing, you have to use another lubricant, one that is better adapted to the purpose. I have effected reductions in cross-sections of 33⅓ per cent, by cold-drawing the tube through a die and over a mandril, when using a proper lubricant.

2 I should not be surprised, though I have had no considerable

experience in using lubricants with tools, if even there they had an effect. I do not know what the surface pressure is in drawing a seamless steel tube, but it must be fully as great as the pressure required to lift the chip in tool-cutting. Seamless tubes have been drawn of high carbon steel, and I should think in that case the pressure would be in the neighborhood of 150,000 lb. per sq. in., at least, and the tubes were drawn quite successfully by the use of proper lubricants. Without the use of lubricants, they could not be drawn.

Mr. Fred W. Taylor. It appears to me that the two cases are not in any way parallel. In the tube-drawing the lubricant can be put on the tube before it starts into the die and a certain amount of it will remain upon it while it passes through it. But how is it possible to make a lubricant run uphill to the nose of a roughing-tool which is ploughing its way into a forging and is completely buried at all times beneath the chip? It would be necessary for the lubricant to force its way uphill between two surfaces under 180,000 lb. pressure. The nose of the tool is buried at all times beneath the chip and the chip travels down on top of the tool continuously at the rate, say of 60 ft. per minute. It would be quite as impossible in the case of tube-drawing to force the oil up through the bottom or rear end of the die between the die and the tube.

Prof. R. T. Stewart. I believe it is the practice in milling to apply the lubricant so that it comes in contact with the cutter before it enters the metal, and some of it will surely cling to the cutter, just as in drawing seamless tubes. I had in mind the case illustrated in the paper, which is upon milling cutters. In milling it is always possible to apply the lubricant to the cutter.

Mr. Fred W. Taylor. In my preceding remarks I had in mind a lathe tool. In the case of a milling-cutter I stand corrected by Professor Stewart—it is possible to get a lubricant onto the lip surface of a milling-cutter before it starts into its cut and in doing fine finishing-work with a milling-cutter a lubricant is frequently desirable. The large milling-cutter under discussion is for taking heavy cuts and in its case the lubricant is of no use. In using this cutter properly an enormous stream of water is thrown on the blades for the purpose of cooling them so as to get a higher cutting-speed.

2 Answering Mr. Smith's question as to the possibility of pouring cast-iron around a high-speed blade, if you treat the blade so as to

give it the best high-speed properties, it must be heated, say, to a high heat between 2000 and 2400 deg. fahr., and then cooled continuously to below 1200 deg. If during the process of cooling from the high heat down to below 1200 deg. it is reheated, even for a short time, the high-speed property will largely disappear, and if during this cooling operation it is reheated for the space of a few minutes, its high-speed is almost entirely lost. Suppose you give a blade its high-speed properties by heating it to a temperature of 2400 deg. and allowing it to cool, and then put this blade back into molten iron which is at a temperature, say, of 1800 deg. This reheating would largely destroy the high-speed properties of the blade. If high-speed steel is heated beyond 1250 deg. and held there for two minutes, the high-speed qualities will be almost entirely gone. And they will begin to return to the blade a second time only after a temperature of 1725 deg. has been passed. Then again, even although its high-speed properties were partially restored to it by heating it, say, to 1800 deg. the grain would be coarsened to a great extent. If high-speed steel is held at a heat above 1800 deg. for even ten minutes it will deteriorate, and if held there for an hour it will become about as brittle as chalk.

3 For cutting brass the tool should have very little if any back-slope or side-slope. A brass-cutting tool should be almost a scraper. Its cutting-edge should not be rounded out in the least, however, or allowed to be in the least dull. Brass tools should for the most part be whitted after being ground. For phosphor-bronze the rate must be different. Tools for cutting steel as hard as fire steel or harder should have 5-deg. back-slope and 9-deg. side-slope. For cutting cast-iron and medium steel they should have 8-deg. back-slope and 14-deg. side-slope; for mild steel, 8-deg. back-slope and 22-deg. side-slope.

Prof. J. Burkitt Webb suggested in regard to the plan proposed for using liquid air as a cooling-agent that it might be as well to conduct the air through the pipes before it was liquefied, and allow it to liquefy in a spray as it came from the nozzle. It would be better than water in some respects as it would not require a drain-pipe to get rid of the waste. He asked if experiments had been made to ascertain how long oil will stick to the surface of cutting tools. He referred to the operation of his viscous dynamometer in which metal discs revolve rapidly in a case filled with water, which is constantly supplied fresh to keep it from heating unduly.

The hands of experimenters had of course been in contact with oily tools, but had been wiped as clean as possible with new cotton waste; yet it was found that oil enough remained on the hands to lubricate instantly the stream of water supplying the case, and reduce the friction 10 per cent. On removing the hand, the friction would creep back to normal in a minute or two.

Mr. Miller. As to the pressures between the cutting tool and chips, why is it when you cut steel dry the surface of the chip is rough and dry, and when you put water on it the surface which has been in contact with the cutting tool is polished?

2 We all know that in chasing threads in the lathe, especially on tool steel, lard oil will enable results in the way of a smooth surface which are not obtainable by lubricating oils or so far as I know with any other substance. If Mr. DeLeeuw noticed whether the surface of the chips which were turned from his steel at the rate of 250 ft. per min. were smooth as when a lubricant is used, or whether they were rough as is ordinarily the case when turned dry, it would throw light upon this matter.

The Authors. In presenting this paper the authors were well aware that they had hardly begun to demonstrate the possibilities of high-speed steel in a milling cutter of the type described, and their chief object in bringing it to the attention of the Society was to reap the benefit of discussion. We are very much pleased, therefore, to adopt the suggestions made by Mr. Miller in regard to the tabulation of results.

2 We want to know, of course, the maximum performance of a milling cutter per inch of face for every size of cutter made. This naturally depends upon the strength of the cutter blade when the cutter is short and on the strength of the arbor when the cutter is long. We do not yet know on what length of cutter the full strength of the driving arbor can safely be thrown, but from experiments we believe that the 3½-in. arbor used to drive our 8-in. cutter 18 in. long would be overloaded before the cutter blades, on an evenly distributed cut.

3 We also know that the cutting speeds were very low, and that with more power and higher cutting speeds our results might easily be multiplied two or three times. The present problem is not what the cutter can do, but how it can be driven at its full capacity. The discovery of high-speed steel has immediately created a general demand for more powerful machine tools, but its adaptation to mill-

ing cutters has progressed more slowly and there are no milling machines on the market today capable of driving our cutter to its full capacity.

4 Though we do not yet know the capacity of our cutter blades per inch of length, we can estimate pretty nearly on the capacity of a driving arbor $3\frac{1}{2}$ or 4 in. in diameter and, allowing 20,000 lb. per square inch as a permissible shearing stress in a 4-in. arbor, we find it capable of driving a cut of about 60,000 lb. on the periphery of an 8-in. cutter. Our cutting speeds on steel varied from 50 to 80 ft. per minute without distressing the cutter blades at all and without any discoloration of the chips, the maximum thickness of which seldom exceeded 0.005 in.

5 In Mr. Taylor's treatise, On the Art of Cutting Metals, 60 ft. is given as the proper cutting speed for a $\frac{3}{16}$-in cut, $\frac{1}{16}$-in. feed; in Paragraph 1186 it appears that the same cut can be taken with a straight cutting-edge 1 in. long at 40 per cent higher speed, or a speed of 84 ft., and in the latter case the thickness of the chip is 0.017 in. It also appears that by the use of water this cutting speed might be increased to 110 ft., all on 33-carbon steel. In our milling cutter, however, we have a shaving not one-third as heavy, and each blade cuts about 5 per cent of the running time and cools off under a stream of water during the remaining 95 per cent. The conditions are therefore particularly favorable for a high cutting-speed and it would not be at all surprising if we could take a cut of 60,000 lb. at a speed of 150 or 180 ft. a minute. This means that 300 h.p. might be consumed in milling and that with an efficiency of 75 per cent in the milling machine 400 h.p. might be required to drive it. Such enormous power concentrated on an 8-in. cutter may yet be realized, but the problem will be to design bearings that will carry 60,000 lb. at a speed of 75 or 80 r.p.m. They cannot be very long to distribute such a load properly and must be kept cool under about 1000 lb. per square inch. A machine with half this driving power would be far beyond common practice today and it is pretty safe to predict that our milling cutter will exceed in capacity any machine that may be built for some time to come, except of course when the cutters are short and the strength of the cutter blades becomes the limiting factor.

6 So much for the future development of the milling machine; but the all-important factor of interest to the user of the present type of milling machine is, how does this cutter compare with the various types of inserted blade cutters now in use. We have carried out a series of comparative tests with various types of inserted

blade cutters and have found that when operated under exactly the same conditions our cutter showed a saving of 50 per cent in consumption of power for a given amount of material removed, and that the life of the cutting edge of the blades was double that of other types of cutters where straight inserted blades were employed.

7 The values of various lubricants and the effects of various lip angles on different materials are questions so thoroughly answered by Mr. F. W. Taylor that we need say nothing further.

EFFICIENCY TESTS OF MILLING MACHINES AND MILLING CUTTERS

By A. L. DeLeeuw, Published in The Journal for November

ABSTRACT OF PAPER

This paper points out the desirability of indicating the power of a machine tool by the amount of metal which it is capable of removing rather than by the size of driving pulley and belt. It describes some tests made for the purpose of ascertaining the metal removed and the capacity of several makes and sizes of milling machines. It also shows the results of tests made for the purpose of finding the net horse power required to remove a given amount of metal under various conditions of feed and speed. It further gives the results of tests determining mechanical efficiency of the feed mechanisms of various milling machines, and shows why it is important that this efficiency should be made higher than is usual. It describes the tests determining the mechanical efficiency of the driving mechanism of one make of machine. It further gives results of tests showing that improvements in cutters, more than improvements in machines, may ultimately reduce very materially the power required for removing metal on a milling machine.

DISCUSSION

Mr. Fred J. Miller. Referring to Par. 4, it is, of course, familiar to the author that although the motor drive has emphasized the fact that machine tools are used for widely varying kinds of work, yet long before the electric motor came into use machine tool builders expected their machines to be called upon to do work varying from the roughest and heaviest to the lightest and most refined. Standard, or commercial, machine tools always have been and probably always will be a compromise based upon that fact.

2 A 16-in. lathe, for instance, can be built capable of taking heavy cuts from steel forgings, say 12 in. to 16 in. diameter; but such a lathe would be nearly useless for a great deal of the work that 16-in. lathes

are called upon to do. Much the same considerations apply to milling machines and this brings up the question as to whether or not a milling machine of the column-and-knee type should be so built as to take very heavy cuts, or be expected to do so.

3 Machines of this type are more convenient of access than any other and are preëminent for the facility with which they can be manipulated. This fact peculiarly fits them for work of a certain kind,—jobbing and tool work, constantly changing in character, for which the machine must be constantly changed in its adjustments and the operator must be able easily and clearly to see what is going on. On such work these features are generally more important than capacity for heavy cuts.

4 Generally speaking, heavy cuts are taken on regular manufacturing work where a number of pieces alike are handled at one time and at a single setting of the machine. On such work facility of access and adjustment, though still important, are unimportant compared with the ability to take a heavy cut when called for.

5 That the knee-type miller is, in its original form, ill-adapted for heavy cuts is shown by the now general adoption of "harness" designed to connect the outer end of the cutter arbor with the outer extremity of the knee and thus reduce the springing and vibration due to reaching out from the supporting column with the cutter arbor and then reaching out with the work-support to meet the cutter. I have seen millers of the column-and-knee type taking surprisingly heavy cuts; but it has never seemed to me that such a machine should be called upon to do it. Where heavy cuts are to be taken machines of other forms seem to be desirable.

6 In Par. 9 of the paper, reference is made to belt power and gear ratio. I have very seldom seen belt speed and gear ratio both specified in a machine tool; it is sometimes done, but I think, not often. Of course if we know the belt width and speed and something of the construction of the machine we can deduce, at least approximately, the turning force that will be applied to the cutter arbor. If we know the belt width only and the gear ratio we can do the same thing.

7 Referring to Par. 19, I think it would be desirable to include with the paper a drawing of the driving gear of the machine designed by the author. I believe such a drawing has been published elsewhere and that the construction is not regarded as a secret. It would help very much toward making complete the record here presented if such a drawing were to be included in the paper.

8 Referring to Par. 28 and 29, it would be interesting to know

something of how the tests there referred to were made. From the nature of the case we would naturally conclude that the force exerted by the cutter against the feed motion of the platen must be about equal to the force exerted by the feed mechanism to move the platen. In fact, in the case of a very deep cut, a considerable proportion of the force exerted in rotating the cutter arbor is not exerted in directly resisting the feed motion, but in lifting the platen of the machine from its seat. It is a familiar fact that, where a stem cutter or a face cutter is applied to the work in such a way that as much of the cut is above the center line of the cutter as below it, practically no force is required for the feed, so long as the cutter is sharp.

9 In general we may say that, other things being equal, the force required to feed the platen of a milling machine will decrease per unit of metal removed per turn, or per minute, as the cut is increased in depth. At a depth of cut equal to the diameter of the cutter, it is probable that very little force is ever required for the feed motion, except to overcome friction, unless the cutter be dull. But for wide cuts of no great depth, the conclusion would seem to be inevitable that the force applied to rotate the cutter and the force applied to move the platen against the cutter are practically equal. If these two opposing forces are substantially equal for shallow cuts, and if, as the cut grows deeper, the force required to rotate the cutter increases in a faster ratio than that required to move the platen, as undoubtedly is the case; and if, as mentioned in the paragraphs referred to, the peripheral speed of the cutter is 40 ft. per min. and of the platen 10 in. per min., we have a speed ratio of 48 to 1 and it is obvious that the power consumed ought to be in the same ratio; or, in other words, the power required for the feed should be slightly over 2 per cent of that applied to the rotation of the cutter, instead of over 66 per cent.

10 It is true enough that results of tests are generally to be preferred to those of deductive reasoning, but it would be interesting to know if the tests that showed that 40 per cent of the power applied to the milling machine to be used to drive the feed-motion, represent actual practice.

Mr. Wilfred Lewis and Mr. Wm. H. Taylor. This paper presents interesting and instructive data in regard to the performance of a milling cutter, and Mr. DeLeeuw is to be congratulated upon the admirable manner in which his work has been done. We have also made some tests upon a milling cutter of different construction, and although we have not gone into the subject in the same way, we are

quite willing to accept the results derived by Mr. DeLeeuw in regard to machine efficiencies as fairly applicable to other machines, upon which we have tried our cutter. We are even willing to admit that the Cincinnati milling machine may be more efficient, and think that 60 per cent would come nearer to the efficiency in our case when the motor is included on account of the additional gearing required for the heavier drive. His method of determining the efficiency of his milling machines by coupling two together and measuring the current absorbed and given off is very ingenious, and gives results in all probability pretty near the truth. We believe, however, that the counter efficiency is never quite equal to the direct efficiency. This is obviously the case where worm gearing is employed, and it must be true to a lesser extent in all cases where speed is reduced through a train of spur gearing and then increased again through a similar train.

2 If Mr. DeLeeuw had carried his experiments further he probably would have determined a higher efficiency for the direct drive of his milling machines. We are willing, however, to accept 75 per cent as a fair average and on this basis it appears that the best results obtained in slab-milling ran from 0.45 to 0.55 cu. in. per min. for one horsepower actually consumed by the milling cutter in cutting 16 carbon steel.

3 In face-milling much better results are obtained and the difference is ascribed to the lip angle of the cutter used in face-milling. It would appear, therefore, that there is no inherent advantage in face-milling over slab-milling if the cutting edges are alike in each case, and our experiments on slab milling bear out this opinion.

4 In our paper on "The Development of a High Speed Milling Cutter with Inserted Blades for High-powered Milling Machines" presented at this meeting, we would call attention to the very pronounced lip angle obtained by the use of our curved blades, and as far as the actual performance is concerned we have made experiments since that paper was written, through the courtesy of the Niles-Bement-Pond Company, demonstrating that it is possible to obtain with such a cutter from 1 to $1\frac{1}{4}$ cu. in. of 25 carbon steel as against $\frac{1}{2}$ cu. in. of 16 carbon steel obtained by Mr. DeLeeuw. This output is estimated on the basis of 70 per cent for the combined efficiency of motor and slabbing machine and this we believe to be a higher figure than could be established by experiments upon efficiency for such a heavily-geared machine. Probably 60 per cent would be nearer the truth and on this basis the amount of metal removed per horsepower would run from $1\frac{1}{4}$ to $1\frac{1}{2}$ cu. in.

5 Mr. DeLeeuw's experiments were made with a $3\frac{1}{2}$ in. by 6 in. cutter on a machine capable of transmitting 11 h.p., weighing about 6000 or 7000 lb. Our experiments were made with an 8 in. by 18 in. cutter on a machine capable of transmitting 165 h.p. and weighing 70,000 lb. We had, therefore, the advantage of taking heavy chips as well as the advantage of the lip angle referred to, and the limiting capacity of our cutter is not yet in sight.

6 It will be of interest to know that some of these chips (exhibited at the meeting) were removed under more severe conditions than has been attempted in slab milling practice with any type of milling cutter or milling machine. Mr. DeLeeuw states in his paper that the cutter was sharpened before each test. We traversed a steel forging $11\frac{1}{2}$ in. wide and 50 in. long five times without sharpening our cutter and after doing this there was no perceptible dulling of the cutting edges. The first two runs were made at a table advance of $9\frac{1}{2}$ in. and $\frac{21}{32}$ in. depth of cut, and the circumference of the cutter was under approximately 25,000 lb. cutting pressure; the third run was made with a table advance of $5\frac{1}{2}$ in., depth of cut $1\frac{1}{32}$ in., with the cutter under approximately 26,000 lb. pressure, and runs four and five were made with a table advance of $9\frac{1}{2}$ in. per min., depth of cut $\frac{3}{4}$ in. with the circumference under approximately 39,000 lb. pressure, making a total of $30\frac{1}{2}$ min. actual cutting time, in which the cutter traversed 250 in. and removed 607 lb. of steel. The cutting speed in all these tests was 70 ft. per min.

7 In regard to the efficiency of the feed mechanism of the Cincinnati milling machine we are not at all surprised to find it as low as Mr. DeLeeuw has discovered, for the simple reason, that the feed is transmitted through a screw. The efficiency of screws is a matter that has come before the Society and has had very careful consideration. It is well known that a screw is one of the most inefficient mediums for the transmission of power that can possibly be employed. It is nevertheless in many cases the best, but we do not agree altogether with Mr. DeLeeuw that the efficiency of the feed mechanism is a matter of first importance. We believe that the rigidity of the feed mechanism is a matter of more importance than its efficiency. The efficiency can readily be increased by increasing the pitch of the screw. Roughly speaking, the efficiency of a feed screw is measured by the pitch divided by the pitch plus the diameter, and for a screw of $\frac{1}{4}$ in. pitch $1\frac{1}{8}$ in. diameter, such as is used on the Cincinnati No. 3 milling machine, the efficiency should be about 18 per cent. If the pitch were doubled the efficiency would be increased to 31 per cent, and

while better efficiency could be obtained by further increase in pitch, this gain in efficiency, however, would be obtained by the sacrifice of rigidity, inasmuch as the steeper the thread, the greater the tortional strain in the screw and the greater the liability to chatter under heavy work.

MR. FRED W. TAYLOR. Mr. DeLeeuw has done admirable work in the experiments which he has described, and work of the kind that is much needed; it is therefore with much hesitancy that I criticise his paper at all, and my criticism is intended to supplement his paper, not to detract from it.

2 His paper gives us facts as to the relative efficiency of three different milling-machines. He has not given us any data, however, which enables us, as engineers, to judge why one of the machines is so much more efficient than the other two. Now in an advertisement, or even in an article written in a technical journal, it is perfectly proper to call attention to the fact that one machine is far better and more efficient than any of the machines competing with it, without giving in detail the reasons. A paper presented to an engineering society, however, should be for the education of its members, and they obtain but little valuable information or education from the mere statement that a result has been obtained, without indication of the exact means by which the result is reached. Engineers want to know not only the result or effect, but also the cause which has produced it.

3 Now the efficiency of a milling-machine is largely the efficiency of its train of driving-gears with the shafts and bearings, plus the efficiency of the cutting-tool. A full description of the trains of gearing, etc., of the three machines should have been given, so that the readers could decide for themselves exactly why one machine is better than the other two.

4 Mr. DeLeeuw of course has this information and I understand would have been entirely willing to present it to the Society if it had been called for by the Meetings Committee or Editor.

5 Again at the end of the paper is a statement which has the appearance of an advertisement. The author states that a new milling-cutter is being patented which is far more efficient than those on the market, without giving even a view of the cutter itself or the slightest inkling as to the cause of this superiority: such a statement should never be permitted in a paper published by an engineering society. I do not think Mr. DeLeeuw is to be blamed for this, but

these facts illustrate the desirability of having a code of directions or advice prepared which shall help the Meetings and Publication Committees in their acceptance and final publication of papers; our editors in their criticism of papers presented; and writers of papers in preparing them for presentation.

Prof. H. Wade Hibbard referred to his earlier enjoyable association with Mr. DeLeeuw in the same designing office and to his own experience with milling machines when learning the machinist's trade in a locomotive-building shop. Going in at 7 o'clock he could hardly get to the high-powered vertical spindle milling machine which he operated because of the large amount of work piled up around it from other machines which ran during the night; but he happened to be one to whom it was a pleasure to see a great amount of metal removed and long before noon the floor was clear. That, too, was before the days of the work of Mr. Taylor or Mr. Gantt, when employees were receiving day wages.

2 One day he twisted off the tool steel arbor of the milling cutter. The foreman looked at the machine and work, saw there was no "bite," smiled instead of upbraiding the operator, and simply ordered him to go to the tool room for another arbor. He then realized that the capacity of the machine had been found and the speaker said that incident might be of interest in the present year of 1908 as showing the capacity of a machine built as long ago as the early eighties, and how its value was recognized by a machine shop contractor.

Prof. J. J. Flather. I wish to add a word of appreciation of the scientific work which Mr. DeLeeuw has done in determining the power required to remove metal by milling and in subdividing that power, placing a portion of it where it belongs, in the feed mechanism.

2 But I wish to protest against the engineer classing "a matter of practical experience, judgment and intuition," as "guess work," as in the first paragraph of the paper. I think that is an engineering estimate and an inference, rather than guess work, and believe this view is really what the author intended. The design of machine tools has been largely based on such estimates in times past, for lack of accurate data, and the engineer has, by a certain process of intuition, and by using his judgment and past experience, put all these factors together, so as to make a very accurate estimate as to what results would be produced under given conditions.

3 The main object of a machine designer should be to produce a tool that will give increased output. The matter of power is of very

little importance. In fact, the cost of fuel in producing power in most of our factories amounts to only two or three per cent, and it does not make a great deal of difference what the power is. What the aim should be is increased output, and any machine that will give increased output, no matter how inefficient it is in the conversion of power, is to be preferred to one that is much more efficient in this regard but has a smaller output.

4 Considering the tools that are in most common use, the lathe and planer and the milling machine, we know, by referring to various tests based on the pound per minute output of metal, that the lathe will remove approximately a pound of steel chips per minute at a cost of 0.4 h.p.; the planer about 2.5 h.p. per pound; and the milling machine approximately 10 h.p. per pound under average conditions. There are so many variables that it is practically impossible to predict how much power will be taken, but the tests show the efficiency of the milling machine to be very low, yet every manufacturer realizes the great saving in labor and time by the use of the milling machine, and the milling machine will be used more and more, because of this saving. This attention to increased output should not in any way prevent us from determining the amount of power required to operate a machine, or its various parts. In fact such tests are often absolutely necessary to a proper handling of the problem; if they lead to a reduction of the power required without interfering with the output, an additional advantage is obtained.

5 The author speaks of the lack of engineering data from which to determine the size of motor to apply to a machine. Today, with the use of high speed steels, this is true to a certain extent, and yet most careful tests have been made, not only to determine the total power required for removing metal and running the machine, but the subdivided power has been determined as long ago as when Hartig was carrying out his experiments in Germany. The experiments showed the amount of power required to run the machine idle, the amount for different speeds, and the amount to remove metal per unit of time. Hartig's experiments included some sixty-nine different machines, with from five to fifty tests on each machine, showing the very wide range of his experiments. Other experimenters, including Vauclain and Halsey, Professor Benjamin, and other members of this Society, have done a large amount of work along these lines, which has been of great value to the designer as well as the user of machine tools.

6 Now, with the advent of the high-speed steel more such experiments are required, and there is a very promising field for some of the research laboratories to take up such problems as have been indicated in this paper, and ascertain how much power is required to operate such machines, and how much may be saved by cutters of different construction, tools of different shapes and different proportions of feed and rate of cutting and various other matters of value to the engineer.

The Author. I would like to go over briefly in chronological order some of the remarks which struck me most vividly. Mr. Miller refers to the milling-machine as a machine especially adapted for tool-room and jobbing work. That has been true almost to the exclusion of everything else. It is true to a very large extent even at the present time, but there seems to be a tendency to use the knee and column type of milling-machine for tool work and jobbing work, for work requiring the fine adjustment to which the milling-machine lends itself, and for work requiring the peculiar feature of the milling-machine, of lending itself to almost any kind of shape one wants to produce; but at the same time the milling-machine is now being used for heavy every-day rough shaping work, plain slabbing, surfacing, etc.

2 One reason why this has not been done in the past may have been the nature of the cutters. It may be that the reason why the milling-machines were used so long almost exclusively for tool-room work was a historical one, but we seem to be rapidly drifting away from this condition; and I thought it would be well, in recognition of this fact, to have some knowledge of the milling-machine outside of its old scope; knowledge of its ability to remove chips. This is not minimizing at all the importance of the milling-machine as a tool-room machine, and I realize fully that the milling-machine may be highly efficient as a machine-tool for a great many lines of work, though it may not be efficient as a user of power. But the milling-machine is also being used more and more for heavy work, and will be used in the future to an even greater extent; and in heavy work an economical user of power is in my opinion very important.

3 I wish to refer also to what Mr. Flather said, that it is not the power that cuts the figure. I would suggest, that we use just as much power as is necessary, and not a bit more, in the machine, and take the rest of the power to drive a fan somewhere in the open air; use the power if you wish to, but do not use it in the machine.

4 The tests which I have described were carried out in order to determine what power is actually required in the machine, and I want to say here, that I realize that these tests are in no sense complete. They have not fully accomplished any of the aims I have set for myself—not even a large percentage; by far the greater part is left undone. It might, perhaps, have been well to postpone the writing of this paper until more complete data were at hand, but the mere fact of bringing this matter up before the Society may assist in starting other people, perhaps better equipped for carrying out such tests, along the same lines, or if they have been working along these lines, may lead them to publish the results of their tests.

5 Mr. Miller further refers to the proportion between the power required for the drive and for feed, and objects more or less to my statement that the pressure against the cutter is practically the pressure against the table. I mentioned this, but with certain limitations, and it may be that the limitations were not put clearly enough. All the cuts taken during these tests were what might be called flat cuts; relatively wide and of little depth; the depth of the cut as compared to the diameter of the cutter was small, and for that reason the upthrust was not very large; and even under these conditions it is not quite true that the thrust against the cutter is the same as that against the table. This is not mentioned in my paper as a fact, but merely as the supporting argument which led up to my realizing the desirability of making some tests on feed efficiencies.

6 I appreciate the remarks made by Mr. Wilfred Lewis in regard to the heavy chips taken by his heavy cutters. I have had some connection with concerns making heavy machines, and have previously spent some time in shops where these heavy machines were being run, on steel, and taking extremely heavy chips. A heavy chip will make me walk around several squares; but the machines I had to deal with would not allow taking such a chip as can be made with a 165-h.p. motor. However, though the tests described do not give any information as to the efficiency of the larger machines, the horse power used on all of the knee and column type machines is, I believe, very much larger than on all of the heavier type of machines on which Mr. Lewis made his tests, and for that reason I believe I do not need to apologize for having limited my paper to the smaller machines. Perhaps the size is not there, but the quantity certainly is.

7 As to the necessity of regrinding the cutter after each series of tests, I may have given the impression that this was necessary, because

the cutter was pulled off after each series of cuts. This was not the case, however. The cutter was reground merely to start every series of tests under the same conditions, and to make the tests on the different machines as nearly uniform as possible.

8 Referring to Mr. Taylor's desire to have causes given as well as effects, in other words to have it shown why one milling-machine should be more efficient than the other, I wish to refer him to the title of my paper, which is not "Efficiency of Milling-Machines" but "Efficiency-tests of Milling Machines:" it is not therefore supposed to give a clear account of everything pertaining to the efficiency of milling-machines, but merely an account of tests made, the methods employed and some of the results obtained; with here and there a guess as to the possible cause. I realize that a complete treatise on the efficiency of milling-machines would be of great interest, but confess that I have not sufficient data for even the foundation of such a treatise. If all the different makes of milling-machines had been tested and one particular make found superior in efficiency, and if this fact had been mentioned in my paper, some statements about the probable cause certainly would have been in order: only four machines have been tested, however, and the result can be of interest only as it shows that a difference in efficiency exists.

9 I believe this paper meets the requirements set up by Mr. Taylor, namely, that it should be of some educational value to the members of the Society, though I realize that it is that only to a very limited extent. Yet the aim of the paper was, by bringing forward methods employed in testing milling-machines, to enable others to work along the same lines, and to whatever small extent this aim has been accomplished, to that extent my paper must have educational value.

10 I am very much puzzled by Mr. Taylor's remark that my statement as to the new milling-cutter has very much the appearance of an advertisement. It would seem to me that to mention that a milling-cutter exists, but not to describe it, nor to show a picture, nor to say who makes it, nor even that it is being made or ever will be made, lacks about all the essentials of a live advertisement.

11 On the other hand I fully agree with Mr. Taylor as to the desirability of having prepared a code of directions or advice, which shall help, among others, the writers of papers to be presented.

FUEL ECONOMY TESTS

By C. R. Weymouth, Published in The Journal for Mid-November

ABSTRACT OF PAPER

In this paper are presented results of tests at the 15,000-kw. power plant of the Pacific Light and Power Company, Redondo, Cal., having steam engine prime movers, crude oil being used as fuel. The fuel economy is stated for tests on a 5000-kw. plant unit at various uniform loads, approximating 2000, 3000, 4000 and 5000-kw.; on a variable railway load; and also for the entire station on a similar variable railway load. The operating and test conditions are fully described.

The results given indicate a remarkable plant economy under all conditions, but the particularly striking feature is the almost uniform fuel economy for the plant unit for all fractional loads from about one-half load up to the maximum load tested. The author believes that the results warrant a careful investigation as to the possibilities in the line of superior plant fuel economy, using the more modern types of steam engines as prime movers.

UNNECESSARY LOSSES IN FIRING FUEL OIL AND AN AUTOMATIC SYSTEM FOR ELIMINATING THEM

By C. R. Weymouth, Published in The Journal for December

ABSTRACT OF PAPER

For a long period engineers have attempted to solve the problem of automatic firing of steam boilers in plants burning liquid fuel. The writer presents, as a solution to this problem, an automatic system of regulation, explaining its development and details of construction, and also its application and successful operation at the Redondo plant of the Pacific Light and Power Company.

An oil pump governor actuated by variations in the boiler steam pressure so varies the oil pressure in a common oil main, and accordingly the simultaneous rate of firing in all burners, as to maintain

practically uniform steam pressure at boilers. This variation of pressure in the oil main is the secondary means for controlling the supply of steam to the burners for purposes of atomization, and also for controlling the amount of damper opening, and thus the air supply for combustion.

Due to this automatic and synchronous adjustment of all the functions of the boiler and furnace, there results on plants subject to fluctuating load an increased boiler economy, which is due to the more uniform rate of firing, the saving in steam used for atomizing the oil and the reduction to a minimum of the air supply for combustion.

DISCUSSION

Mr. Geo. H. Barrus. The author states in the first paragraph that this plant gave a "notable economy," which means, I suppose, that it gave a better economy than other large electric steam power plants. It would add much to the value of the paper if he would present examples of what has been accomplished by other plants, so that we could see to what extent the economy shown is really notable.

2 It would also be interesting, and of great value, if he would tell us something about the economy of the individual elements of the plant, i.e., what was the efficiency of the boilers taken by themselves; also what was the steam consumption of the engines per i.h.p. per hour. With information of this character, the members of the Society would be able to form some idea themselves as to whether the plant was economical. Upon this subject there is no intimation in the paper as presented.

3 It seems to me highly improbable, in connection with a test of such a character as the one described, involving, as the mechanical papers have told us, such a large pecuniary bonus, and one which required the assistance of such a large corps of testing men as the number referred to, that some one did not make an evaporative test of the boilers, and steam consumption test of the engines, to determine their individual economy. Very likely the author has such data, and I will be glad to hear from him on that point.

Prof. William Kent. The papers are very interesting as showing what can be done with oil and with reciprocating engines on the Pacific coast. The statement in Par. 68 of the paper on Fuel Economy Tests, that "Inasmuch as the steam turbine gains largely in apparent economy due to increase in vacuum, similar reductions should be made in the stated economy of such plants, and correspond-

ingly in the reported fuel consumption," indicates that the author considers the result of the test a proof that reciprocating engines are as good as turbine engines; and seems to be equivalent to saying it is believed that the steam turbine is good because it can utilize a high vacuum, which the reciprocating engines could not do economically: and that for this reason we must deduct from the economy of the turbine the amount it gets from the high vacuum and charge that against it. I do not think that is fair to the turbine.

2 These tests show very good results in kilowatt-hours per barrel of oil. Between the barrel of oil and the kilowatt-hours there are many variable conditions. First, there is the oil-burner. I understand that they have in San Francisco a new burner which is more efficient, especially in the regulation of the air supply. It appears that part of this higher economy in the San Francisco test is due, not to extraordinary efficiency in heating surface of boilers, but to the regulation of the air supply. Second, the efficiency of the boilers in San Francisco is due to the theoretical fact that it is possible to get a greater percentage of efficiency out of oil than out of coal. I know of no large plant in the East tested with oil. We have to test with coal, where we are troubled with ashes, the large excess of air necessary to burn coal properly, and many disadvantages which the writer would credit to the coal pile, because it suffers these disadvantages.

3 Thus we have in favor of oil, the theoretical economy higher than that of coal and the diminution of the excessive losses due to unregulated air supply in coal firing. The records of the test fail to show, however, how much of the total economy between kilowatt-hours and barrels of oil is due to the reciprocating engine. As far as I can find, not a single point is made in favor of the reciprocating engine, other than the general statement that because we have the great economy the reciprocating engine is a good engine.

4 In making a test between the reciprocating engine with oil as fuel under the boilers, and a turbine engine with coal, we have so many variables that from such a test-record a statement of the relative value of the reciprocating engine and the turbine is impossible. The only way to get such a statement is to have a test made with the turbine in San Francisco with oil, with the same boilers and with same adjustment of air supply, and Professor Jacobus to watch it, and we will get as good results out of the turbine, if not better, than have been obtained from the reciprocating engine.

Prof. William D. Ennis. It is difficult to say whether in reality this plant is showing notable economy. A heat consumption of 25,228 B.t.u. per kw-hr. is perhaps unprecedented, if it is maintained in the ordinary operation of the plant. This rate, noted during the 15-day test, under expert superintendence, is, however, not comparable with the 2 to $2\frac{1}{2}$ lb. coal consumption rates of our best large plants day in and day out as the load factor comes. It is to be regretted that the details of the boiler performance are not given, as this would permit of judging as to the economy of the engines. Assuming that the boiler efficiency was 0.80, and the efficiency from engine cylinder to switchboard 0.855, then the heat unit consumption from line 24 of Table 1 was about 215 B.t.u. per i.h.p. per min.—not at all an exceptional result with superheat, under test conditions

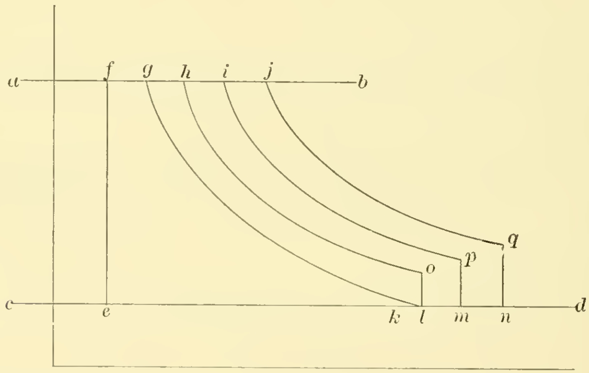


Fig. 1 Comparison of Rankine and Clausius Cycles.

With engines of this size, operating at 180 lb. pressure, and with certainly a fair vacuum—28.334 in.,—one would almost expect a better result. If these were service tests, however, then the results are of course most excellent. But the results do not seem to be those to be anticipated in regular running.

2 The proposal to compare engine performances with the limits possible in a standard cycle has been made before. There is no good reason for calling this standard cycle that of Rankine. It is true that Rankine recognized that the terminal pressure might be *equal to*, greater than or less than the condenser pressure (*The Steam Engine*, 1897, Art. 278); but all of his computations are based on the existence of some terminal drop. On the other hand, Clausius (*Fifth Memoir, On the Application of the Mechanical Theory of Heat to the Steam*

Engine) clearly describes what I suppose we have all had in view as the standard cycle; viz, one in which adiabatic expansion is followed by isothermal condensation without intermediate drop in pressure. The expression for efficiency of this cycle is perfectly definite, based on the upper and lower temperatures: that for the Rankine cycle is not. The illustration may make this clear. The Rankine cycle between the limits *a b* and *c d* might be any one of *fjqne, fipme* or *fhole;* the Clausius cycle can be only *fgke.*

Mr. J. R. Bibbins. Much information of an important character has been omitted from this very interesting and valuable paper; namely, data on individual efficiencies of engine and boiler plants respectively. It may have been difficult to obtain such data during the test, but they are certainly essential to the conclusion reached by the author, whereby the reciprocating engine is credited, by inference if not directly, with the major part of the excellent results obtained although no data are presented which give the least possible ground for such a conclusion.

2 Suppose, however, we take the author at his word and compute the efficiency possible from a steam motor working under the precise conditions stated. Referring to the 15-day test, the average load was about 3660 kw., and it is stated that the engines were rated at 4000 kw. Presumably, therefore, the engines during this 15-day test were operated at approximately their point of best economy. Now on the other hand, consider a turbine plant similarly rated at or near its point of best economy (just before the overload valve comes into service). If we supply this turbine with steam at 180 lb. pressure, 82 deg. superheat and a vacuum of 28⅓ in., or even 28 (allow for drop between condenser and turbine), it is a question whether the author would place his opinion on record that the economy thus obtained in connection with the same oil-burning boiler plant would be inferior to the corresponding economy obtained by test on the reciprocating engines. In other words, with a given boiler plant and given conditions of operation, does the author claim for the reciprocating engine economy superior to that which recent tests of large turbines have demonstrated beyond reasonable doubt? This is to be inferred from his closure. In Par. 68, the author states that, "inasmuch as the steam turbine gains largely in apparent economy due to increased vacuum," the reported economy from turbine plants should be reduced accordingly for comparison with engine-driven plants. The vacuum reported in the Redondo tests is fully

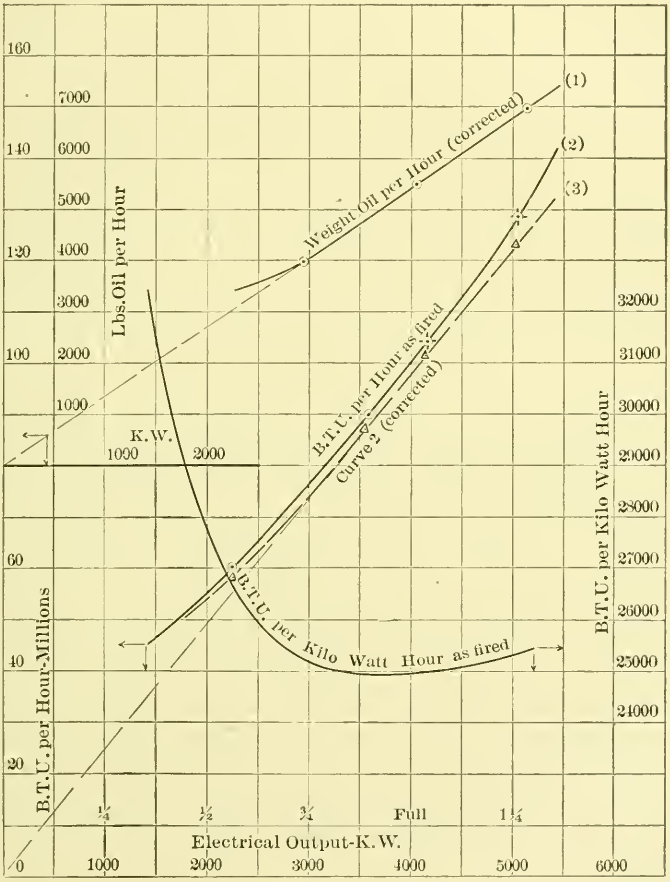
as high as is obtainable in the best turbine plants in the country —28 and 28.4 in., therefore the necessity for correction is not apparent.

3 The crux of this whole matter seems to be the efficiency of the boiler plant with oil fuel. Three years ago the United States Naval Bureau of Steam Engineering conducted extensive tests with both oil and coal fuel upon a marine water-tube boiler, with the specific purpose of ascertaining the comparative boiler efficiencies respectively obtainable. Detail figures are not at hand, but the average ratio of evaporation between coal and oil, under otherwise identical conditions, was in the neighborhood of 10 to 15; and under normal power-plant conditions of land practice, the ratio was reported still higher, 10 to 17. Correcting for the difference in heat-values of fuel burned, it is apparent that the efficiency of an oil-fired boiler plant is from 10 to 20 per cent higher than that of one burning coal.

4 Assuming then a turbine plant generating a kilowatt-hour on 15 lb. of steam, under the conditions obtaining during the Redondo test, and a boiler plant burning coal with the efficiency of an oil-fired plant, evaporation would be at least 10 lb. of water per pound of coal, and the overall fuel consumption 1.5 lb. per kilowatt-hour or 21,000 B.t.u. per kilowatt-hour, an economy superior to that obtained at Redondo. That the turbine economy above noted is quite conservative is apparent from the results of tests upon a large turbine at the Waterside Station of the New York Edison Company. An average economy better than 15 lb. was obtained under conditions of 175 lb. pressure, 96 deg. superheat and 27.3 in. vacuum. It does not seem, therefore, that the reciprocating engine has demonstrated itself in the Redondo tests capable of any extraordinary economy, *per se*.

5 The shape of the economy curve *A*, Fig. 3, seems to establish a rather novel load characteristic for a power-plant unit; viz, practically constant economy over an extraordinary range of load. If we consider the reciprocal of this curve in pounds of oil per kilowatt-hour, and again convert this into total oil per hour plotted against load, we have a so-called Willans line, shown as curve 1 of the accompanying figure. This Willans law is highly valuable in analyzing the rational performance of both steam and gas plants, and at a glance indicates unusual results. In this case, the load-oil consumption curve is practically a straight line from the origin above about 3000 kw., curving rapidly below this point, a phenomenon for which

it is difficult to find a good explanation. If now we plot a similar Willans line for load B.t.u. per hour, taking the observed values (line 24, Table 1), curve 2 is obtained. This line of total heat consumption appears entirely rational as a characteristic of a steam engine governing by cut-off. It shows a decided curvature, the relative heat consumption increasing on both heavy and light loads.



The point of tangency of a radial line from the origin indicates the point of best economy to be in the neighborhood of 4000 kw., which is entirely rational.

6 Finally, if the values obtained by correcting oil consumption according to contract stipulation are plotted (line 23, Table 1), the

Willans line flattens out into the straight line 3, above 3000-kw. load, but shows an even more marked curvature below this load. This would indicate a practically constant heat consumption of the unit from 3000 kw. up.

7 The reasons for these peculiar characteristics are not clear, and from the known characteristics of a reciprocating engine tested at different loads, as was done in this case, it may only be inferred that the reasons lie in a variable boiler-plant efficiency. To my knowledge there is no prime mover possessing a straight-line characteristic through the origin, i. e., an economy remaining constant with the change of load. Consequently, we may look only to the boiler plant for an explanation of these results. And it is to be hoped that the author may be able to submit further data. The Redondo tests are so thoroughly authenticated in every respect as to preclude the usual possibility of errors of observation, so that the opportunity is exceptionally good for throwing further light upon oil-fired boiler performance. This would be particularly desirable in connection with the discussion of the methods of firing in the author's second paper.

Mr. I. E. Moultrop. This is an interesting paper upon a subject which has been somewhat neglected by the Society in recent years, and in the writer's opinion more papers on similar lines would be of value. Mr. Weymouth has made a careful test of the Redondo plant, and is to be congratulated on having built a fine station and one which shows remarkably good economy.

2 In view of the care with which this test was made and the large number of trained observers employed, it is to be regretted that more information was not obtained at intermediate points in the cycle which would point out specifically how this fine economy was obtained. There is nothing to show whether it was obtained in the boiler plant, the engine plant, the condenser plant, or the general station design. The author apologizes for the vacuum and attributes the lack of a better one to the temperature of the cooling-water, which he considers high. The vacuum seems to be remarkably good under the given conditions, however.

3 Mr. Weymouth is in error when he states that Eastern power stations obtain their higher vacuum only by the use of cooling-water at a temperature near the freezing point. The writer knows of a number of large power stations where the condensing apparatus is designed to give vacuums inside of 1½ in. absolute with the circulating

water from 5 to 10 deg. higher than the temperature stated in the paper; and he is inclined to think that a material increase in the cooling surface of the condenser, other conditions being the same, would have considerably improved the vacuum in this instance.

4 Some of the conclusions drawn by the author seem unwarranted, especially where he unfavorably compares large turbine stations in the East to his station. There is nothing in the paper which justifies the assumption that the engineers did the best thing when they selected steam engines for the prime movers. As the superior economy of steam turbines over reciprocating engines as prime movers for electrical generating stations has been so well demonstrated, and as the vacuum carried on the plant during the test was not especially good, only the boiler plant is left to be considered in accounting for the good results obtained. Tests in other places, and notably by the United States Geological Survey, indicate that boilers fired with good fuel oil show a considerably higher economy than with first-class steam coal.

5 The central station manager naturally wants a generating plant which will show a fine performance on the B.t.u. basis, but he is much more concerned in having a generating station which will put the maximum of kilowatts on the switchboard for a dollar spent in operating; and while the geographical situation of the Redondo station was doubtless such that fuel oil was a wise choice, no cost-information is given, and there is therefore no means of determining whether or not an engineer in the middle or eastern states would be justified in building a station for the use of fuel oil.

6 There is one point in the operation of this station which the author has not touched, and which I hope he will include in his closure, and that is the matter of the successful removal of the cylinder lubrication from the condensed steam before it is returned to the boilers. This has been a very serious objection to the use of surface condensers with steam engines in power plants, and it would be extremely interesting to know, either how the oil is successfully removed or what difficulties and extra expense are entailed in operating the plant by reason of more or less oil getting in the boilers.

Mr. A. H. Kruesi. The subject has been well covered by those who have already discussed the paper. The economy hinges on the efficiency of the boilers. It appears that the conclusions on the last page are hardly justified without more data as to where the economy of the plant is to be found. The boilermakers might claim a

large part of the credit and as has been shown a large part of it is due to the use of a fuel which is little short of ideal. It can be controlled instantly, produces very little flue dust, and has many other advantages which need not be detailed here.

2 It may be noted that the conclusions as to the flexibility of these units make a virtue of a necessity of the steam engine. By the same argument it might be contended that it is desirable to use five 1000 kw. turbines, instead of one 5000 kw. turbine, to reduce the liability of breakdown and increase flexibility of operation.

Mr. F. W. O'Neil. The paper upon Fuel Economy Tests is of value in showing the performance of engines at fractional loads. As pointed out in Par. 58 the losses are proportionately greater at fractional loads, yet as the difference in losses at full and fractional loads is relatively small, the economy of the engines fairly approximates the economy of the whole station.

2 The result obtained of 252.8 kw.-hr. per bbl. of oil, or 25,288 B.t.u. per kilowatt hour, is by no means extraordinary when compared with the performance of engines reported to the Society in the past and when the size of the plant, the high vacuum and superheat are taken into account, as well as the high boiler efficiency possible when firing with oil.

3 The thing which is extraordinary in this report is the low guarantee accepted by the purchaser of 170 kw.-hr. per bbl. of oil, especially when it is considered that a large bonus was to be paid for every kilowatt hour secured over and above this amount. The difference between the guaranteed economy and the economy obtained on test is 32.8 per cent, or, in other words, the plant used 32.8 per cent less fuel than would have been consumed had the actual economy corresponded to the guarantee. This fact, together with the conclusion of the writer, might lead some to believe that the difference between the guaranteed and obtained economy represented the accuracy with which designing engineers were able to predict engine performance. The writer believes it desirable to call attention to the fact that the above difference is by no means a fair measure of the ability of steam engine designers to predict engine performance.

4 It is to be regretted that water was not weighed, or, if it was, that the amount was not included in the results, so that the separate performance of boilers, engines, etc., could be segregated.

THE TRANSMISSION OF POWER BY LEATHER BELTING

By Carl G. Barth, Published in The Journal for January

ABSTRACT OF PAPER

This paper offers an advanced theory for the transmission of power by leather belting, and mathematically takes account of a number of facts brought to light years ago, but never before fully explained or utilized in belt formulae. It also presents, in practical working diagrams, the results obtained by numerical substitutions in the formula developed, and illustrates a slide rule on which almost any practical question relating to the transmission of power by leather belting may be quickly solved. The complete paper consists of a main body setting forth the leading results and conclusions; an appendix containing the leading features of the mathematical work; and an unpublished supplement, on file with the Society, to which have been relegated the details of the mathematical work, as well as some additional conclusions, refused publication in the paper.

DISCUSSION

Mr. Henry R. Towne. The earliest investigation of this subject was by General Morin, of the Conservatoire des Arts et Métiers, who gave, in a volume published, I think, about 1850, the results of his experiments to determine the co-efficient of friction of belts on pulleys, and algebraic formulae to express the power transmitted under varying conditions. For many years these formulae were accepted universally. General Morin's experiments were made under laboratory conditions.

2 In 1867 I made a series of experiments to determine, under conditions approximating those of actual use, the co-efficient of friction and also the tensional strength of commercial belting. These experiments, and a discussion by the late Robert Briggs on the mathematical conditions involved in the problem, were published in the Journal of the Franklin Institute in 1868. Under the title of

the Briggs and Towne Experiments, the conclusions thus reached were quoted and accepted for many years, by Professor Rankine, Professor Reuleaux, Professor Unwin, and many other technical writers. Mr. A. F. Nagle, in a valuable paper contributed to the Transactions of the A. S. M. E. in 1881 (Vol. 2, p. 91), accepted the results of the Towne experiments as the basis for his discussion of the mathematical problems involved.

3 The Transactions for 1886 (Vol. 7) contained two important contributions to the literature on this subject. One of these is a paper by Professor Lanza (p. 347), which first prominently calls attention to the importance of *speed of slip* as a factor in the transmission of power by belting. The other is a paper by Mr. Wilfred Lewis (p. 549) giving the results of a long and elaborate series of experiments in the shops of William Sellers & Co., and demonstrating, among other things, that the proposition first enunciated by General Morin, and accepted unquestioningly by all subsequent authorities, namely, that *the sum of the tensions is constant* $(T_1 + T_2)$, does not hold true in all cases, and is therefore erroneous.

4 The Transactions for 1894 contain another most valuable paper, by Mr. Fred W. Taylor (p. 204), giving the results of his large experience covering many years in the use and observation of belting under the conditions of actual practice. Many new and important deductions from the investigations of Mr. Taylor are summarized in this paper and in the writer's discussion of it (p. 238). Mr. Taylor's most important deduction effected a departure from the long accepted assumption that the co-efficient of friction is constant, to a recognition of the fact that it *varies with the tension per square inch* (or other unit of area) of the belt, and hence that there is substantial advantage and economy in the use of thicker belts. He was also the first to demonstrate and set forth clearly the economic gain to be derived from the scientific care of belting.

5 Finally, Mr. Carl G. Barth, availing himself, as he has stated, of the work of his predecessors, especially that of Mr. Lewis and Mr. Taylor, has completed, for the present at least, the study of this problem, which has thus extended over some sixty years, giving us an elaborate and apparently a conclusive demonstration of the soundness of the mathematical conclusions finally reached, furnishing *working formulae for practical use,* and presenting a most ingenious application of the *slide rule* to the problems involved in the practical use of leather belting.

6 The Society is to be congratulated on including in its roster of

membership the names of all those since General Morin who have taken the lead in ascertaining the facts and in determining therefrom the rules which govern the application of leather belting to industrial uses.

7 Mr. Barth's system has now been in use for about two years in the works of the Yale & Towne Mfg. Co., Stamford, Conn., where it has accomplished a substantial increase in economy and efficiency.

Mr. Wilfred Lewis. It is only by carefully conducted experiments and careful analysis of the underlying principles involved, that substantial progress can be made in the field of engineering; and I am clearly of the opinion that Mr. Barth has discovered and formulated principles of the greatest practical value in the solution of the problems of the transmission of power by leather belting.

2 It is difficult in a paper of this kind to separate the practical from the theoretical without discarding the most valuable part of the undertaking; the laborious work done by the author in order to reach his conclusions, and recorded in the appendix to this paper, is really the basis of the superstructure reared by him and gives the reader some idea of the immense amount of patient research and good sound reasoning employed in building up a complete analysis of the subject.

3 Mr. Barth is the first, I believe, to analyze the peculiar elastic properties of leather, and to demonstrate in a convincing way the effects of these properties in the use of belting under varied conditions. His analysis of the combined effects of elasticity and sag is very original and ingenious, and even aside from the results obtained his methods cannot fail to interest investigators in other fields of research. Difficult and complex problems have been solved by making certain assumptions and approximations that are quite allowable as the means to an end, and it is in these short cuts from the intricate and unwieldly to the simple and practical that he has displayed such remarkable ingenuity. At the same time, for those not enough interested in every step to care to follow a mass of mathematical formulae, Mr. Barth has presented his conclusions in a form available for immediate use.

4 Popular impressions, even though well founded, are often exaggerated beyond reasonable bounds, and while it is true that horizontal belts of considerable length are preferable in the transmission of power to vertical or shorter ones, it will be a surprise, I believe, to engineers, that there really is so little advantage in a

long horizontal belt over any length of belt in any position. All this results from the exposure of the fallacy that the sum of the tensions is constant, a belief exploded 23 years ago, although the far-reaching effect of the exposure on the transmission of power by belting has never before been so clearly expounded.

5 The author's treatment, also in the unpublished supplement to the appendix, of the effect of variations in pulley diameter upon the transmission of power, I believe to be absolutely original, and his conclusion that a belt will slip on a driven pulley before it will slip on a driver of the same diameter indicates a subtlety of analysis rarely displayed in our proceedings, and is a fair index of the pains-taking care with which the whole paper has been written. Although not perhaps of very great practical importance, as a new discovery, the analysis might well be included in the appendix to the paper, rather than in the unpublished supplement to the appendix.

6 It is safe to say that in the slide rule, engineers who wish to make the best use of leather belting will have at their command an instrument capable of solving at once many problems that might otherwise consume a good deal of valuable time.

Mr. W. D. Hamerstadt. A number of highly valuable papers have been presented before the Society from time to time, dealing with the subject of belt transmission, which have, in the main, contributed only to our better understanding of specific problems involved; it has remained until the present time for someone to assemble the results of such former efforts into a final perfected theory, as has so admirably been done by Mr. Barth.

2 For several years past, the writer has been somewhat closely associated with work on pulley and belt drives, and recently has had occasion to compare the results of some carefully conducted experiments with the results which might be expected from the use of formulae as proposed in Mr. Barth's paper. Considering the many variable factors, these comparisons are remarkably favorable, and for average conditions of operation, the relationships which have been established would appear to hold quite true.

3 One almost vital point of consideration in the actual design of belt drives seems to have been touched upon but lightly, however, and then in a manner which, as the author himself has stated, leaves some room for discussion—namely, values of the coefficient of friction to be used in the formulae given, under varying conditions of service. While the value of the coefficient of friction will not affect

the theory of belt transmission as given, it will seriously affect the size of drive required to do a given work, and having now a good theoretical basis for work, and assisted by the observations of others, additional experimental work might well be done for the determination of such values, using as nearly as possible good average leather belting and operating under actual conditions of service.

4 Based partly on the conclusions of Professor Lanza or of Mr. Wilfred Lewis, as given in early papers before the Society, and partly on the very mechanical reasonableness of the thing as he puts it, Mr. Barth assumes that, given a belt and pulley, the value of the coefficient of friction to be used in any case will be determined to a great extent by the velocity with which the belt slides on its pulley. Taking then a curve representing average relations between these two factors for any convenient speed of belt, values are at once available for the coefficient of friction for any speed of belt and any condition of slip desired.

5 That there exists some ground for such reasoning cannot be denied, but a brief comparison of results actually obtained from tests performed from time to time, on belts operating at widely different speeds of service, leads one seriously to question its application to practice. Such comparisons rather lead one to expect more nearly correct results when drives are designed on the basis of relative slip between belt and pulley.

6 Fig. 1 and Fig. 2 show a series of curves representing, for a number of different tests, the relation existing, first between values of the coefficient of friction and velocity of slip, and second, between values of the coefficient of friction and percentage of slip. Information regarding the data from which these curves were plotted is given in the table. Letters designate corresponding tests in either set of curves.

7 Referring to Fig. 1, it will be noted that for each different speed of belt there appears to exist a clear and well defined relation between values of the coefficient of friction and velocity of slip; at lower velocities of slip more especially, the value of the coefficient appearing to be higher for slow-speed belts and lower for high-speed belts. Obviously then, any curve representing a relation between values of the coefficient of friction and velocity of slip holds true only for that speed of belt for which it is plotted and cannot be used indiscriminately for all speeds of belts. The effective range of velocities of slip which would be used in the design of belt drives would probably be from 0 to 25 ft. per minute, as indicated in Fig. 1, and the error

which might be incurred then in using either of the extreme outside curves shown (even though they do not represent maximum possible range of speeds of belts) would vary from about 70 per cent to values almost infinitely large. The curves B_1 and C_1 indicate the relation that would presumably have held true between values of the coeffi-

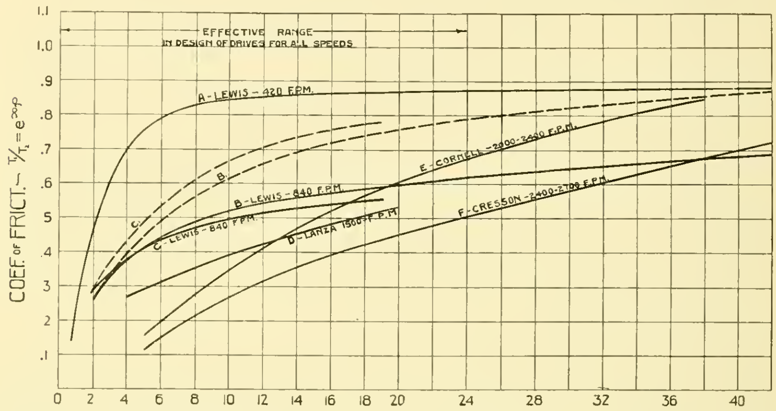


FIG. 1 RELATION BETWEEN COEFFICIENT OF FRICTION AND VELOCITY OF SLIP

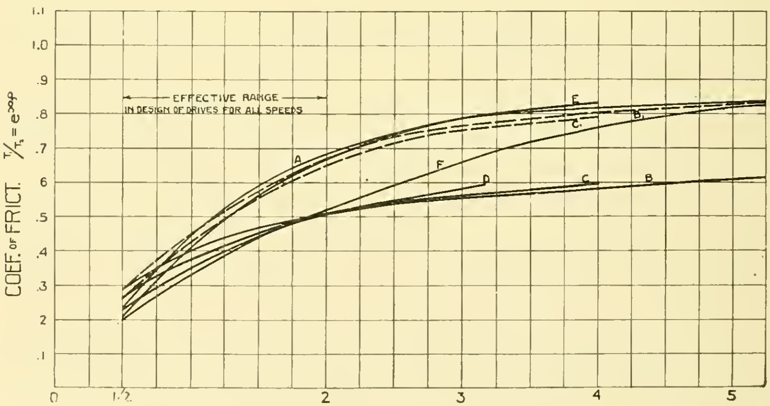


FIG. 2 RELATION BETWEEN COEFFICIENT OF FRICTION AND PERCENTAGE OF SLIP

cient of friction and velocity of slip for belts B and C had those belts been such as to have shown a maximum value of the coefficient equal to that of belts A, E or F.

8 From Fig. 2 it will be noted that for any given speed of belt the same general relation between values of the coefficient of friction and per cent of slip appears to hold true, and belt drives designed on

such a basis might then reasonably be expected to give anticipated results at all speeds of operation. When curves B_1 and C_1 are plotted to represent higher values of the coefficient of friction for belts B and C, as in Fig. 1, the similarity in form of these curves is remarkable —the more so as they represent tests performed in some cases over twenty years apart.

9 But it is not the intention of the author to attempt to establish at present a positive basis of determination of changes in the value of the coefficient of friction. It is hoped, however, that certain proposed experimental work having as its object the determination of such a basis will shortly be undertaken; and results of such work might be presented to the Society later. In its present connection, the manner in which changes in the value of the coefficient of friction occur is a matter of some importance and the seeming fallacy of the present accepted theory appears worthy of further consideration.

10 As an example of the results to be expected when drives are designed on the basis of velocity of slip of the belt, as proposed in the paper, let two extreme conditions of service be taken. one a drive operating at a speed of 400 ft. per minute and at a slip of about 2½ per cent, the other a belt operating at a speed of 5000 ft. per minute and at a slip of about 1 per cent. The slow-speed belt would then have a velocity of slip of 5 ft. per minute on each pulley, the high-speed belt of 25 ft. per minute. Referring to Fig. 7 in Mr. Barth's Appendix, it will be found that for such velocities of slip the values of the coefficient of friction to be used should be respectively 0.38 and 0.53; but the maximum value of the coefficient of friction at even the highest velocities of slip of 60 ft. per minute, as shown, is only about 0.57 and it appears then that the overload capacities of all drives is limited to about that value. This amounts, in the case of the slow and high-speed belts given, to about 50 and 7½ per cent respectively.

11 It is safe to say, however, that fully 80 to 90 per cent of all high-speed drives are used in connection with electrical machinery, and for such work drives must have an overload capacity of at least 50 per cent of their rated capacity. It would be necessary then, for such practice, that belts be originally designed for correspondingly lower velocity of slip, amounting in this case to a velocity of about 5 ft. per minute. The high-speed belt, noted above, at ordinary conditions of service would then operate at a relative total slip between pulley and belt of only one-fifth of one per cent.

12 While the author has had occasion to observe a large number

TABLE 1 DATA USED IN MAKING COMPARISONS SHOWN IN ILLUSTRATIONS

Curve	Test	Speed of Belt Ft. per Min.	Belt			Pulley		Remarks
			Kind Leather	Size Inches	Condition	Kind	Diam. Inches	
A	Wilfred Lewis: Table 4, Exp. 209–259	420	Oak-tanned Double	$4 \times \frac{5}{16}$	New, Dry and Clean	C. 1.	10	Belt Run under Severe Conditions, Tests made to Determine Point of Slip at which Belt Leaves Pulley.
B	Wilfred Lewis: Table 1, Exp. 60–75	840	Single	$5\frac{1}{2} \times \frac{7}{32}$	Old, Good and Pliable	C, 1	20	....
C	Wilfred Lewis: Table 2, Exp. 105–135	840	Double	$2\frac{1}{4} \times \frac{5}{16}$	Old Dry and Clean Quite Pliable	C. 1.	20	....
D	Prof. Lanza: Vol. 7, Trans. West Belt, Exp. 1–11	1500	....	....	....	C. 1.	......	$T_1 + T_2$ Assumed Constant and Corresponding Error Made in Calculated Results.
E	Cornell University: Exp. 1–82	2000–2400	Oak-tanned new, single	$5 \times \frac{3}{16}$	Dry and Clean	C. 1.	24	
F	Geo. V. Cresson Co.: Catalog B, 1906, Exp. 1–100	2400–2700	New, single	$3 \times \frac{3}{16}$	Dry and Clean	C. 1.	24	Tests made at Cornell University

NOTE: All of the belts given were in good working condition when tested, being free from oils, grease or dressings. Belts B and C had been subjected to more or less oil in service before testing, however, which accounts in part for lower relative values of their coefficients of friction.

of successful high-speed drives on electrical machines, just the condition of slip here indicated has never been noted, but in almost every case the overload capacity of the drives has been noted as a function of the relative slip between belt and pulley.

13 When it is further considered that, generally speaking, the point at which the belt will leave its pulley is a function of the per cent of slip and is taken independent of the speed of belt, it certainly appears that the relative slip cannot but play an important factor in determining values of the coefficient of friction to be used for such drives.

Mr. Fred. W. Taylor. The first thought of many of our members on seeing a paper on Belting is, Why should a paper on this subject be presented to our Society? With the advent of the electric drive, is not belting so rapidly becoming a back number that a paper on this subject will arouse but little interest? Certainly, judging of the comparative value of the belt drive and the electric drive by the relative number of papers written on the two subjects of late years, one would conclude that the belt drive is worthless. The electric drive, however, is a new element in engineering and one in which progress has been both rapid and sensational, while the average engineer has concluded that but little new remains to be known about belting.

2 The belt is one of the oldest and most commonplace of the elements used in shop practice, so that engineers designing new establishments or remodeling old ones, who wish to be up-to-date, naturally incline toward the use of the electric drive rather than the belt. There is no doubt, however, that this has led to the use of the electric drive in many instances where the belt would be far more economical and satisfactory in almost every way.

3 In the average machine shop, for instance, the writer is prepared to say that for more than half of the machines the belt drive can still be used with greater economy and with more satisfactory results than the electric drive; only on the assumption, however, that the belting is systematically cared for. The most serious objection to the belt drive as generally used is the loss of time due to interruption to manufacture when retightening and repairing, and to the loss of driving power and consequent falling off in output, when the belt is allowed to run too slack. Belts can be tightened and repaired at regular intervals after working hours, however, with the use of spring-balance belt-clamps to get the right tension, causing thus practically no interruption to manufacture.

4 As will be explained later, it has been shown by an accurate record kept through a long term of years, that in the average machine shop the average cost per belt per year is $2.25. This includes the original cost of the belt, plus all labor and materials used in maintaining, repairing and cleaning it throughout its life. No similar statistics for the maintenance and renewal of the motor drive seem to be available, but I think no one will contend that the latter can in any way approach this economy.

5 In a great number of cases the electric drive should be used in the machine shop, but in the writer's judgment the burden of proof still rests on the motor drive to show in each case that the economy in delivery and removal of work more than makes up for the extra cost of installation and maintenance, and for the delays incident to repairs, blowing out fuses, etc. In large machines economy lies on the side of the motor drive in many instances, but with almost all small machines the belt drive should still be used. In view of these facts, the belt drive is hardly a back number. In fact, the manager of one pulley manufactory told me recently that even during the dull times his company had been selling from twelve to fifteen thousand pulleys per month.

6 Under the rules still in common use, a large proportion of belt drives are badly designed, and belts are used under heavier tensions than they should be for all-round economy. Therefore there is ample justification for a paper such as Mr. Barth's. All who have experimented with belting or who have been interested in the mathematics of belting, will be filled with admiration at the remarkable analysis which Mr. Barth has made of this difficult problem. Even Mr. Lewis, whose experiments and scientific conclusions have properly been given first place among writings on this subject, tells us in his paper that life is too short to attempt a complete mathematical solution of the problems involved. Yet this is precisely the task which has been accomplished by Mr. Barth. I have personally seen the patient research and hard labor of months which Mr. Barth has put into this work, purely from an unselfish devotion to the interests of our profession, and I am glad to bring this fact to the attention of the Society. It is such work as this that will give our Society high standing throughout the world.

7 As engineers, mathematics (elementary mathematics, to be sure) is one of our daily implements, so that we are qualified to appreciate the work of the pure scientist or mathematician who devotes his life either to advances made in the field of pure mathematics,

or in the application of mathematics to what may be called the field of pure science. The work of these men, while invaluable to the world in the long run, is but remotely useful to engineers; the peculiar mathematical ability displayed by Mr. Barth, however, should appeal to us as engineers far more even than the work of those engaged in pure science. Mr. Barth has displayed that analytical ability, rare with mathematicians, which has enabled him to simplify mathematical formulae so complicated as to be unsolvable, and to make them immediately practical and useful without materially deviating from their value.

8 He thus puts into our hands for daily use a new and valuable piece of knowledge, or implement, but unlike so many of our best theorists and investigators, he does not stop with developing his useful formulae. He has further embodied this knowledge in a slide-rule, so simple that by its use anyone, whether familiar with mathematics or not, can solve practically all belting problems at a glance. I hope that either Mr. Barth or someone else will arrange to have this slide-rule made available to engineers at large, at a reasonable price, and accompanied by practical directions for its use. Such implements are invaluable aids in the everyday work of the engineer, and should be in every drafting-room in the country.

9 The experiments of Messrs. Briggs and Towne and those of Messrs. Bancroft and Lewis will remain for many years as classic monuments in the development of our scientific knowledge of belting laws; but Mr. Barth's remarkable analysis of the work of former experimenters, supplemented by his accurate though less voluminous experiments on the elastic properties of belting and on the rate and extent of the fall in tension of belts, has rendered his conclusions as to economical speeds and the proper sizes of belts more reliable than those of any previous writer. His final recommendations should be accepted, therefore, rather than those in the papers of Messrs. Towne, Lewis, or the writer.

10 There should, in the writer's judgment, be added to Mr. Barth's paper a clear numerical statement giving the exact tension per inch of width to which belts of average thickness, both double and single, should be retightened each time they require tightening, and this statement should be given a prominent place in the paper, so that it can readily be found.

11 It may be of interest to know how the figure of $2.25, quoted earlier in the paper as the cost per belt per year, was found.

12 In the new machine shop of the Midvale Steel Company,

beginning in the year 1884, the writer experimented[1] with all of the belts in the shop, in practical use; and upon the comparative values of the four leading types of leather belting then in common use. This experiment lasted nine years with belting running night and day (equivalent to eighteen years running ten hours per day). Exact records were kept of all items affecting the life and economical use of belting, and at the end of the experiment, among other items, it was found that the average belt cost (under the ordinary belt rules then in use, as, for example, those used on the cone pulleys of the various machines; and on the ten hour basis) $3.34 per belt per year for the first cost plus all labor and materials used in maintenance and repairs. These are double belts, averaging 29 ft. long by 3.8 in. wide.

13 These belts were run under too high tension for economy, however. They lasted on an average 14 years (ten hours per day). The remaining belts in the shop, which proved more economical, lasted on an average not far from 28 years (ten hours per day), and cost per year per belt less than $2.50 for first cost and maintenance, etc. And this although they were materially larger than the cone belts, averaging 50 ft. long by 4.84 in. wide. The machines in this shop averaged much larger than in the average shop, and an investigation has led me to the conclusion that in the average shop the average belt would be about equal to a 3-in. double belt, 20 ft. long. The first cost plus the maintenance of this belt would not be greater than $2.25 per belt per year.

14 I hope that Mr. Barth will add to the body of his paper before it is reprinted in the Transactions one or two paragraphs emphasizing the necessity for systematic care of belting wherever it is used, by a man properly taught this work. The care of belting should be entirely taken out of the hands of the men who are running the various belt-driven machines, and belts should be systematically retightened at regular intervals, with belt-clamps fitted with spring-balances, each belt having the tightening strain carefully figured in advance. Belting should also be cleaned at regular intervals, and should be softened with the small amount of belt-dressing which is needed to keep it in perfect condition. A laborer can be quickly trained to tighten and care for all the belts in the shop during the

[1] These experiments are described in a paper entitled Notes on Belting, presented before the Society December 1893, and forming part of Volume 15 of the Transactions.

noon hours and on Saturday afternoons and at other times when the shop is not running.

15 Two elements of great importance in Mr. Barth's paper seem to me almost certain to be lost, even to those especially interested in the subject of belting, buried as they now are in the unpublished supplement. These should be taken out of this supplement and printed in the appendix when the paper finally appears in the Transactions of the Society. These items are, The Influence of Pulley Diameters on the Sum of the Tensions of the Belt, and a *condensation* of the discussion of the formula, Ratio of Effective Tensions, l^{fa}. Not only has this discussion a great theoretical interest, but the conclusions have a distinct practical value.

Mr. Charles Robbins. As Mr. Barth has said so much on the question on belting, and my purpose towards the elimination of the belt, I will discuss the paper from that point of view.

2 Mr. Barth's data will be of great service in the future to certain classes of industries using the belt to a great extent; more particularly to textile mills, where the belt has been in use for years, and the proposition is essentially that of constant and uniform speed.

3 When we took up the question of applying motors to that class of work we were informed that the principal objection was too great variation of speed. Their stated requirement seemed to be an electric drive which would give a speed as close as the mill engineers seemed to think they had, a problem that we took up with some hesitation, but in applying to spinning frames the alternating-current motors, which, as you know, are constant-speed machines and run at a very uniform speed, we discovered that the productive capacity of the frames was very largely increased.

4 This led us to make some tests as to the loss of speeds, or slip of belts, and their lack of uniform operation. The net result in using the induction motor instead of the belt is an increased production of at least seven per cent, and in some instances even ten per cent. Probably some of this increase was largely due to the fact that the belting systems tested were not designed in accord with Mr. Barth's system; but I do not believe that a system of belts will ever approach the uniform and constant speed of an induction motor. The fact remains that with the average system of belts the motor drive, on account of its uniform speed, increases the production of almost any class of machinery.

5 The question of efficiency may be classified as (1) the primary

efficiency from the engine shaft to the shaft of the driven machine; (2) the economies which result from the use of the electric motor drive. These secondary economies, which are undoubtedly the most important, will vary with the class of industry to which the electric motor is applied. It is greatest in those industries where the load time factor of the installation is lowest and where the inherent characteristics of the electric motor are of greatest value. These characteristics are as follows:

a Ability to adjust the speed according to the demands of the work.

b Absolute certainty of a uniform and constant speed.

6 While these two characteristics may seem to be opposed, they are important factors in the increase of production of different types of machines. As widely separate examples: for a machine tool the readiness with which the speed of a motor may be varied to the right quantity for the work required contributes to its increase of production; on the other hand textile mill service requires an absolutely constant and uniform speed, which is obtained from the induction motor.

7 In determining the value of an electric motor drive the essential point is always the secondary, or accruing economies from its use, rather than the primary economy, although when the primary is added to the secondary the net result will be extremely satisfactory.

Mr. Geo. N. Van Derhoef. This paper develops in a clear way principles that we have heretofore been forced to regard as intangible enigmas, and will no doubt live as one of the engineering classics of the Society.

2 The property of leather belts of continually stretching under service conditions, belongs also to other forms of transmitting bands, and is possibly inherent in any form of transmitting band possessing a fibrous structure. This means that maximum and minimum limits of initial tension must be used, or devices employed to take care of the increasing length, in which case the belt may always be operated under minimum tension, lighter weight pulleys and shafting may be employed, and the load on the bearings minimized.

3 While there seem to be very few recorded tests on the amount of energy consumed in the rapid bending and unbending of belts, it seems to be a well-defined belief among engineers that the energy lost through this cause is less than is commonly supposed. I am inclined to agree with this, and also believe that the loss due to reverse bends in belts, either in energy consumed or in destructive action on the belt, is probably smaller in amount than is usually supposed, provided these bends have a relatively large radius.

4 The author's plan of proportioning belts so that the slack will be taken up at approximately regular intervals of time, regardless of speed or power transmitted, is excellent from a theoretical point of view. He is obliged, however, to divide belts into two classes —machine belts and countershaft belts, under different initial tensions, and therefore with different periods between adjustments. I think it will be absolutely necessary to provide more classes. In some cases first cost is of greater importance, and in other cases the expense or inconvenience of taking up belts is the main consideration. With a large belt, running night and day, the stopping of the drive to take up the belt is a serious matter. In the case of many drives, however, this is a matter of small moment.

5 I have had considerable experience with large quarter-twist belts, running from 12 to 20 in. in width, for connecting horizontal and vertical shafts, and have seen results that appear incredible in view of much of the theoretical data published on belting. These belts were under high unit-tension, and always subjected to reverse bending over deflecting idlers. Probably one reason for the success of belts of this kind is the automatic regulation, within limits, of the slack-side tension, due to the belt working up and down across the face of the pulley on the vertical shaft. As far as I have observed, belt drives of this kind, when properly designed and erected, have been as satisfactory as horizontal belts with about the same distance between centers.

6 Possibly the larger unit-stresses frequently used necessitate a slight actual slipping of the belt on the pulleys, with some corresponding increase in the coefficient of friction. This should not necessarily be regarded as poor practice, but simply as a factor to be weighed against savings in first cost, friction losses, etc. There seems to be no fundamental objection to slipping within certain limits, provided such slip is a constant quantity. All belts are continually sliding, to some extent, on the surface of the pulleys, due to the theoretical creep caused by the elasticity of the belt. A little more would not necessarily be serious. The surface of a well finished leather belt is such that sliding on a polished iron pulley will not cause much harm provided the heat generated by the slip is dissipated with sufficient rapidity to prevent the temperature of the belt surface from rising too high. This, of course, involves a loss of energy, as do very large belts under low tensions, and the crowning of pulleys. The writer desires to emphasize that due consideration should be given to all the factors involved.

7 Spring belt-clamps should be used wherever practicable, and ought not to be very expensive if manufactured in reasonable quantities. In the majority of cases, however, we shall have to be satisfied with figuring belts properly, and leave the actual initial tension to fate.

8 The idea that the maximum working-stress of a belt should not be determined by its ultimate strength is, I believe, correct. This becomes more apparent in studying transmission ropes. It is a well-known fact that the maximum unit-stress for a manila transmission rope should be of such amount that the side-pressure between the lubricated fibers of the rope will not cause abrasion when the ropes bend over the sheaves, and the fibers slide on one another. Probably some such internal action takes place in the case of leather belts. In transmission ropes the ultimate strength bears a greater ratio to the proper maximum working stress than is the case with leather belts. Manila rope is therefore a very safe transmitting band.

9 The constant lengthening of belts in service has its counterpart in ropes. Where a rope is simply carried around two sheaves, as in the separate rope system, the general equation of the rope is without question similar to that which the author has shown to be true of leather belts.

10 The continuous system of rope transmission, with its automatic tension carriage, has the slack-side tension maintained at a minimum. This is one of the fundamental reasons why the continuous system can transmit the same amount of power at the same rope speed and with the same rope life, with less rope than is possible with the separate wrap system. A few years ago the continuous system was looked upon by most engineers with considerable scepticism; its enormous development in the last quarter of a century is due simply to its basis on absolutely sound mathematical principles.

Mr. Walter C. Allen. My contribution to the discussion will relate to the practical results obtained from the installation of an improved method of caring for belting, rather than to the technical phases of the question. In this connection a brief description of the working out of the improved system in the works of the Yale & Towne Mfg. Co. may prove interesting.

2 The problem of transmitting large amounts of power by means of belting is not a serious one with us, as our power is for the most part transmitted electrically; each room is provided with one or more motors, and the power is distributed from them through line

and countershafts to the machines. The great majority of our belts are small, and many of them run at high speeds. Altogether we have about 4800 belts, so that their proper maintenance is an important and somewhat difficult problem.

3 Early in 1905, at Mr. Barth's suggestion we undertook an investigation of our belting and the methods employed in its upkeep, as a result of which we decided to adopt a system of caring for belting recommended by Messrs. Taylor and Barth. For the sake of brevity I have divided my notes into comparative statements, of the conditions before and after the adoption of the new method as affecting each element of this important subject. It may seem that the conditions existing before the installation of the new plan were distinctly bad, but I venture to say that they were as good as those in many manufacturing establishments at the present time, if not better. The improved conditions, however, are so infinitely superior to the old that by comparison the latter appear extremely antiquated and crude.

4 *Tensions.* Under the old plan we had no means of knowing with any accuracy the tension of a belt. It was left to the individual judgment and experience of those doing the repairing, so that inevitably the tensions of the belts varied in proportion to the variation of judgment of the repair men.

5 The first step in the reorganization was the building of a belt bench and the provision of tension scales such as are shown in Fig. 6. These are used now altogether for the determination of tensions.

6 *Records.* Under the old regime we had no records whatever of our belts.

7 Under the new plan we have a record of each belt showing its location: its type, i. e., whether open or crossed, countershaft or machine belt; kind of leather; thickness, width and length. These records also show for each belt the dates of inspection.

8 *Organization.* Under the old plan our millwrights cared for the heavy belts, but the repairing was done only when the belt gave way, or stretched so that it failed to transmit the necessary power. The small machine belts were cared for by the individual machine operators, many of whom knew absolutely nothing about belting, and in some cases our investigations showed that ignorant operators had attempted to tighten a belt by cutting out a piece, and, finding that they had cut out so much that the belt would not go over the pulleys, were then compelled to cut out still more and set in a piece in order to make the belt long enough to do the work. In these

cases also the belts were not repaired until they actually gave out through breakage or failed to give the necessary pull.

9 Under the new plan a gang of four men do absolutely nothing else but inspect belting and attend to the repairs and retightening. A belt room has been provided in which is an annunciator, and a series of push buttons are arranged at the telephone central, so that in case of an accident to a belt the foreman or gang boss can call the belt man easily. In a plant as large as ours the annunciator results in a great saving of time.

10 A tickler system was installed by means of which the belt gang are notified regarding the belts to be inspected each day. After the inspections are made these tickler cards are returned to the office where the proper records are made and the ticklers put back for the next inspection.

11 These belt men take their lunch hour from 11 to 12 o'clock, working during the noon hour, and are thereby enabled to repair many belts which could not be repaired when the works are running, without loss of time to other employees.

12 *Fastening.* Under the old plan there was no fixed rule regarding the fastening, rawhide lacing and belt hooks being used indiscriminately. Under the present plan Jackson wire lacing, put into the belts by means of a machine, is universally used. For continuous belts, under the old plan we used a kind of glue which took from three to ten hours to set satisfactorily. Under the present plan we are using a special glue which will set hard in thirty minutes. This also results in a saving of time in the case of an accident to continuous belts.

13 *Belt Dressing.* Under the old plan comparatively little belt-dressing was used, but in many cases rosin was used through ignorance of the fact that it causes the belting to deteriorate rapidly. We now use entirely Plomo belt-dressing, which is extremely useful and tends to prolong rather than to shorten the life of the belt.

14 *Reclamation of Oily Belts.* Under the old plan no reclamation was attempted, but at the present time we reclaim a considerable amount of belting each year. Belting damaged on the edges is cut down and used for narrower belts, short pieces are scarfed and glued together and the oil is taken out of oily belting and the belts used over again.

15 *Kind of Belting.* Several kinds of belting were used under the old plan, but we have gradually standardized our belting until at the present time practically nothing but a high-grade of oak-tanned belting is used.

16 *Cost of Up-Keep.* Of course there was no method of determining the cost of maintenance under the old plan. Our records show that during the year 1906 the labor-cost of maintaining our belting system was 96 cents per belt. During 1907 it was 73 cents and during 1908, 45 cents. This decrease has of course been due to the increased efficiency of the men doing the work and to the fact that experience has indicated where inspection periods could be lengthened out, and also to the fact that the belting is now in such condition that expensive break downs seldom occur.

17 The foregoing statements describe briefly the various features of the old and the new plans: a summary of the advantages of the new plan follows:

a Decreased cost of belting. The cost for the year 1907 was only about 60 per cent of that for 1906, despite the fact that we installed more new machinery in 1907 than in 1906.

b Increased efficiency of machines, due to the fact that the tensions are maintained much more uniformly than formerly.

c Continuous production by both men and machines, due to decreased interference due to belt-breakdowns.

d Uniform type of belt lacing, decreasing danger to employees.

e Decreased cost of maintenance.

f Under the present plan the cost of maintenance appears as a separate item where it can be watched and compared with that of previous periods to determine the relative economies, while under the old plan the figures were combined with a mass of others so as to make it impossible to determine how much it had cost.

CONCLUSION

18 When we first commenced to install the new system we had all sorts of trouble as is generally the case with any new thing. The plan was opposed by foremen, gang bosses and workmen, each of whom had an idea that the new tensions were entirely wrong, and that the machines would never do the work properly, unless they could adjust the belting according to their individual ideas. One of the best evidences of the value of the present plan is that this antagonism has entirely disappeared, and what was at first con-

sidered by many an interference and a hindrance is now accepted as a help and is believed to be entirely satisfactory by those competent to hold an opinion.

Mr. Taylor. The original experiments at the Midvale Steel Works were started in 1884; 17 years later, when all the machinery in that shop was taken out, one of the belts, which was of the type of those run under proper rules, that is, approximately the low tension suggested by Mr. Barth, had run all that time night and day under heavy tension. During this time it had required tightening only nine times, and at the end of the equivalent of 34 years of ten-hour service that belt came off its pulleys and was immediately put to work on another machine, in good condition. This instance of the life of a belt properly taken care of and properly tightened will be a surprise to the man accustomed to see a belt go out of use in from two to five years. This statement has just been determined.

Mr. Dwight V. Merrick.[1] As I am interested in chain drives, I will draw attention to some experiments made by Hans Renold, Ltd., of Manchester, England, and embodied in a pamphlet issued May 1908, comparing the relative efficiency of chain and belt drives on automatic machines. Mr. Renold claims that with the chain drive the output was increased 20 per cent, fewer drills and parting tools were used, and a better finish was obtained on the work. He says: "The tool did its work *unflinchingly* at every part of the revolution of the spindle—no more and no less." He further states that the wear and tear on the spindle and countershaft bearing was considerably reduced. These statements were so striking that the Link-Belt Company, with which I am associated, decided to make further tests. In one of these which I was detailed to make I maintained a constant feed and speed and used the same tools with each drive, and in all cases the tool was used until it became necessary to re-grind, the object being to cut off as many pieces or drill as many holes as possible before this condition was reached. The tool when chain-driven did considerably more work than when belt-driven. I quote from my report as follows:

2 These tests were made on a 3 in. by 36 in. Jones and Lamson turret lathe, with "blue chip steel" cutting-off tool $\frac{3}{16}$ in. wide, cutting off cold rolled shafting $2\frac{1}{2}$ in. diameter, feed 0.012 in. per revolution.

[1] Dwight V. Merrick, Link-Belt Mfg. Co., Nicetown, Philadelphia, Pa.

TABLE 1 RESULTS OF EXPERIMENTS ON A 3 IN. BY 36 IN. JONES & LAMSON TURRET LATHE 0.012 IN. FEED PER R. P. M.

Mark on Tool	Kind of Drive	Pieces No.	Metal Cut by Tool Inches	Cutting Speed Ft. per Minute	Condition of Tool	Time Minutes	R.P.M. of Spindle
2	Belt	6½	8.125	94	Ruined	5.91	143
	Chain	16	20.	94	Ruined	14.70	143
	Belt	9	11.25	94	Ruined	7.15	143
5	Chain	7⅞	9.843	128	Ruined	4.81	196
	Belt	4⅞	6.093	134	Ruined	2.72	203
4	Belt	1	1.25	134	Good	0.51	203
	Belt	¼	0.312	151	Ruined	0.12	231
	Chain	1	1.25	126	Good	0.54	193
	Chain	⅞	0.937	151	Ruined	0.39	231
1	Belt	1	1.25	129	Good	0.53	197
	Belt	½	0.625	146	Ruined	0.15	223
3	Chain	1	1.25	129	Good	0.53	197
	Chain	1	1.25	149	Fair	0.44	228
	Chain	⅜	0.468	195	Ruined	0.15	299

Note: A higher cutting speed was obtained by the chain drive.

TABLE 2 RESULTS OF EXPERIMENTS ON A DRILL PRESS WITH NEW ⅞ IN. DIAMETER CARBON STEEL DRILLS, 0.018 IN. FEED PER REVOLUTION, IN A SOFT CAST-IRON BLOCK, 3 IN. THICK

Mark on Drill	Kind of Drive	Holes Drilled Number	Metal Cut by Drill Inches	Cutting Speed R.P.M.	Condition of Drill after Drilling Holes	Time Minutes	R.P.M. of Spindle
1	Belt	31	93	62.2	Started to ruin	18.91	273
1	Chain	57	171	60.5	Corner rounded, needed grinding, starting to ruin	35.91	264
2	Chain	37	111	62.2	Starting to ruin	22.57	273
2	Belt	20	60	62.2	Starting to ruin	12.20	273

Note: A great many more holes were drilled by the chain drive.

TABLE 3 RESULTS OF EXPERIMENTS ON THE SAME DRILL PRESS AS IN TABLE 2 WITH NEW $\frac{23}{32}$ IN. DIAMETER CARBON STEEL DRILLS, 0.018 FEED PER REVOLUTION, IN A VERY HARD CAST-IRON BLOCK, 3 IN. THICK

Mark on Drill	Kind of Drive	Holes Drilled Number	Metal Cut by Drill Inches	Cutting Speed R.P.M.	Condition of Drill after Drilling Holes	Time Minutes	R.P.M. of Spindle
3	Chain	17	51	28.0	Starting to ruin	19.84	148.8
3	Belt	14	42	28.4		15.40	151.4
4	Chain	17	49½	28.0	Started to run on 17th hole 1½ in. deep	18.48	148.8
4	Belt	13	39	28.2	Started to ruin	14.44	150.0

Note: More holes were drilled by the chain drive, but the percentage of gain was not anywhere near as great as in Table 2.

3 Care was taken in forging, treating and grinding the several tools used, to insure uniformity in their cutting qualities; but to obviate the possibility of the results being affected by the cutting qualities of the different tools, each tool was used with both drives.

4 One of the tools cut off 16 pieces when chain-driven before it became necessary to re-grind, and only 9 pieces when belt-driven. The cutting speed in both cases was 94 ft. per minute, feed 0.012 in. per revolution, and another tool cut off 8 pieces when chain-driven against 5 when belt-driven. In this latter case the cutting speed was 130 ft. per minute, feed 0.012 in. for chain and belt.

5 As the cutting periods in the above test were so short, two more series of tests were made with longer continuous periods. These tests were made on a drill press with new $\frac{7}{8}$ in. carbon steel drills in a soft cast-iron block, 3 in. thick. The same drill was used on both drives, and was carefully and uniformly ground for each test.

6 One of the drills when belt-driven drilled 31 holes before it became necessary to re-grind, but when chain-driven the same drill drilled 57 holes; the cutting speed in both cases was 62 ft. per minute, feed 0.018 in., and another drill at the same speed and feed drilled 37 holes when chain-driven, against 20 when belt-driven.

7 The other series of drill tests was made on the same drill press, with $\frac{23}{32}$ in. carbon steel drills on a very hard cast-iron block, 3 in. thick. One of the drills when chain-driven drilled 17 holes before it became necessary to re-grind, against 14 holes when belt-

driven; the cutting speed in both cases was 28 ft. per minute, feed 0.018 in. per revolution, and another drill did 17 holes, chain-driven, against 13 belt-driven, same feed and speed as above.

8 The results were so gratifying that further tests are being made on four similar automatic machines, at our plant in Indianapolis, two fitted with belt drives and two with chain drives. The same feeds and speeds will be maintained with each drive throughout the series of tests, but a variety of tests will be made to establish the maximum efficiency of both belt and chain drives, to the best of our ability. The results will all be tabulated and published in a pamphlet in the near future.

9 The accompanying tables contain the tabulated results of my experiments.

Mr. F. A. Waldron. After listening to this paper, one naturally asks the question, What is its commercial value? Mr. Allen has answered this very well, but I will give a little of my own experience with the system.

2 At the plant of the Yale & Towne Company, most of the responsibility for the condition of belts, prior to the author's going there, was placed with me and I am willing to take any criticisms. I became an ardent advocate of Mr. Barth's work on belts, however, particularly because of the practical results obtained.

3 After leaving the Yale & Towne Company, I had occasion to purchase a Barth bench and spring-balance and apply the elements of the system without spending a large amount in replacing countershafts. I established the system of varying tensions on different machines. A light countershaft would not stand as heavy tension on the belt as the author originally prescribed. Tensions on belting, lengths, taking up, etc., were recorded. A record of complaints received in the millwright department for a specified number of countershafts and machine belts had been kept, and for ten days or two weeks before installation something like 150 complaints came in. After complete installation of the Barth bench and scales and the Barth system, the complaints dropped to 80 for two weeks, and six weeks later to 35, showing the commercial results of systematic care of belts.

4 Belts as low as $1\frac{1}{2}$ in. wide, and some heavy double belts three to four inches wide, were the limits on size.

5 This system was installed almost at the cost of my reputation, and on leaving that concern I supposed that the belt bench and

bench-scales would be relegated to the scrap heap. Having an opportunity to put in a belt-bench and scales elsewhere, however, I wrote the firm asking if they did not want to sell the bench and scale and they said "no."

Mr. A. A. Cary. I was much interested in Mr. Allen's remarks concerning the employment of Mr. Barth's system and formulae for the selection and proper application of belts to drive the numerous machines at the Yale & Towne plant, but explanation of one essential point is needed to show how this can be practically accomplished.

2 As I understand, one important factor required in the formula used to determine the proper initial tension to which each belt must be subjected when put in place, is the horse-power to be transmitted by that belt. It has been stated that 4000 belts are used in this plant, operating perhaps one-half that number of machines. I would like to know the method employed to determine the power requirements of each of these machines so as to obtain the required value of this factor when the formulae are used.

3 If we merely *guess* at the power required, we depart from the exact scientific method of determining information in our belt problems and recede toward the "rule of thumb" method, as a formula is no more exact than is the value of the most uncertain quantity employed in its solution. If Mr. Barth can give us any "short cut" method for determining the power required by machines to be driven by belts, he will funish information that will give his formulae a very practical value.

4 I have had considerable experience in determining the power required to operate machinery by use of the steam engine indicator, with dynamometers of several forms and through readings obtained from electrical instruments, but this work is complicated and requires considerable time and preparation. I hope that Mr. Barth can give us a simpler method, with which the value of his excellent paper will be greatly increased.

Mr. A. F. Nagle. This paper does not pretend to present any new facts, but sets forth, in mathematical formulae and diagrams, data obtained by Messrs. Lewis, Taylor and others. It also diagrams some simple arithmetical computations. As a work of mathematical study and diagrammatic representation, the paper is admirable, but as a practical aid to a busy engineer, it seems to me too complicated. The only part which holds my attention is the diagram in Fig. 3,

giving the horse power of belts at different velocities, and of two types spoken of here as countershaft and as main drive belts, but more commonly designated as "single and double thickness." The reason for this distinction is that while the stress in the net solid body of the leather is taken to be the same in each case, in "single" belts the joint is a butt joint and is laced. This cuts away more of the belt than where the belt is of double thickness, lapped and cemented, or riveted; the difference being in the character of the joint rather than in the thickness of the belt.

2 For comparison then, we can take Mr. Barth's estimate of the relative strength of these belts, as 160 to 240 or 1.0 to 1.50. Mr. Towne found these to be as 1.0 to 1.82, and in my early studies, I was inclined to adopt this ratio; later, however, I have used the ratio of 275 to 400 or 1.0 to 1.45.

3 The belt problem is very far from being one of pure mathematics. As in most engineering problems, there is about 5 per cent of scientific knowledge involved, and fully 95 per cent of good judgment based upon experience. We rarely know the exact power to be transmitted except in the case of prime movers. The arc of contact, the velocity, and the stress we are willing to put upon the leather, are all easily determined, but we cannot decide upon the coefficient of friction by formula. A new leather belt upon an iron pulley may not have a coefficient of friction of 25 per cent, while the same belt, well worn and well groomed, will give 65 per cent in a clean, dry room; put the same belt in a wet place, like a tannery, or a dusty place, like a stone-crushing plant, and we have an entirely different coefficient.

4 It seems to me that the designing engineer, even though he understands the mathematics of the belt problem, if ignorant or unappreciative of the practical conditions under which the belt works, will be liable to make a mistake. On the other hand the engineer familiar with the conditions, but ignorant of the mathematics involved, is also liable to error in his conclusions. A cautious man will endeavor to err on the safe side, feeling no doubt as our venerable ex-President Mr. John Fritz did, who when remonstrated with for making some machinery needlessly strong, replied, "If I do, nobody will ever find it out."

5 On general principles, it is of course desirable to work belts, like other members of a machine, with large coefficients of safety, but engineering, in its last analysis is a question of finance and we must "hew as close to the line" as possible. Mr. Towne found the ultimate strength of laced belts to be 200 lb. per inch width ($\frac{7}{32}$ in.) thick,

and used $\frac{1}{3}$ of this, or $66\frac{2}{3}$ lb. as a safe working stress. Mr. Towne also found a coefficient of friction of 42 per cent to be safe. The general practice of the day has been quite close to these factors, but if I understand his diagrams correctly, Mr. Barth has departed far from them.

6 In 1881 I read before the Society a paper giving for the first time, I believe, a belt formula which took cognizance of the effect of centrifugal force. The data used therein were based principally upon Mr. Towne's experiments. The results obtained were well within the safe limits of previous practice for low speeds, but at high speeds my formula showed the deviation. Common formulas gave results (see Kent, Mech. Eng. Pocket Book, p. 879) as follows:

For single belt 1 in. wide, 600 ft. per minute (1) 1.09 h.p. (2) 0.65 h.p. (3) 0.60 h.p. (4) 0.82 h.p. Nagle 0.73 h.p. Barth gives only 0.40 h.p.

For double belt, common formula 1.17 h.p. Nagle 1.24 h.p. Barth 0.68 h.p.

7 For the purpose of giving a clear conception of Mr. Barth's deviation from the others, I repeat my formula here:

$$h.p. = \frac{C.\ V.\ t\ w\ (S - 0.012\ V^2)}{550}$$

C is a constant expressing the adhesion of the belt upon the pulley under a unit of stress of belt. Its value is expressed by the equation $C = 1 - 10^{-0.00758\,f\,a}$ where a is the arc of contact and f the coefficient of friction. The other quantities are as follows:

V = velocity in feet per second.

S = Stress upon leather per square inch, which I have taken at 275 lb. for laced and 400 lb. for riveted belts.

t and w are the thickness and width respectively in inches.

$500\ f\ t\ w$ = horse power per sec.

8 To illustrate the solving of this equation, let a = 180 deg. and f = 0.40, then

$$180 \times 0.40 \times 0.00758 = 0.54576$$
$$01^{-0.54576} = \log 10 \times 0.54576 = 1 \times 0.54576$$

0.54576 is a logarithm of which 3.513 is the number. This being a minus coefficient, we must take its reciprocal or 0.284; substracting

this from 1, we get 0.716. The result could have been obtained by subtracting the log 0.54576 from 1, giving 1.45424, and this gives 0.2846 as its number direct.

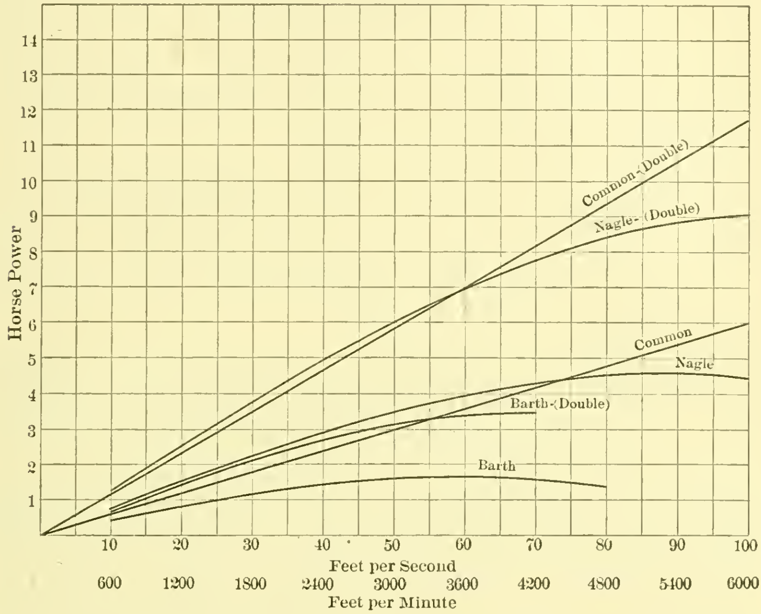


FIG. 1 COMPARISON OF DIFFERENT BELT FORMULAS, BASED UPON BELTS 1 IN. WIDE AND $\frac{7}{32}$ IN. THICK FOR SINGLE AND $\frac{1}{4}$ IN. THICK FOR DOUBLE BELTS

9 In Kent's Mechanical Engineering Pocket Book, p. 878, tables are given based on this formula, which facilitate its use. I wish to call attention to the wide divergence of Mr. Barth's conclusions from those commonly used as well as from my own, as plotted in Fig. 1 herewith. I have reduced his figures to the same thickness as mine, namely $\frac{7}{32}$ in. for single and $\frac{1}{4}$ for double.

10 This work has been done somewhat hastily and I hope the author will check it at least so far as relates so the interpretation of his diagram. If my work is correct, I am puzzled to understand why his tables of belt horse power differ so much from mine.

PROF. WM. W. BIRD. I feel very much pleased and highly complimented to see the results of Mr. Barth's mathematical analysis of

my experiments on belt creep. On a few points, however, I am still in doubt in regard to his general conclusion. I believe:

a That the elasticity of a belt varies with the velocity and that at very slow speeds the sum of the tensions would remain constant, while at high speeds, if it were not for the centrifugal force, that the sum would increase practically with the load. If this is true, a belt will improve with higher speeds and will not reach a maximum at 4000 ft. per minute as shown in Fig. 3.

b That in determining the size of a belt for a given load, the diameter of the smaller pulley should be considered. A belt will do relatively less on a small pulley than on a large one, other conditions being the same.

c That the crowning of the pulleys should be considered as it affects the life of the belt.

d That the carrying capacity of a belt should not be given in terms of square inches of cross section, as a double belt with one square inch of cross section will not transmit as much as a single belt of the same cross section.

2 I have recently made some tests on compound or rider belts and have been somewhat surprised at the relative movements of the main and rider belts with various pulley ratios, from which I have concluded that if these belts were glued together, as they would be in a double belt, numerous internal stresses and strains must be set up when the belt passes over a pulley, especially over a small one.

3 The crown is a very serious matter on a small pulley, as the following figures will show. Take a 4 in. pulley with a crown of 0.2 in. in the diameter, if the belt wraps 180 deg., the length in the middle of the belt will be 0.31 in. greater than on the sides; this means a stretch of 0.05 in. per inch or 1000 lb. stress on middle fiber, taking modulus of elasticity as 20,000 lb. The belt must slip or be ruined, for this stress does not include load or initial tension and is in itself enough to stretch the belt beyond the elastic limit. The slipping necessary to adjust this stress must influence the friction and slipping of the belt as a whole.

4 I would like to have Mr. Barth answer a question which I have been asked a great many times,—why does the sum of the tensions in a belt increase with the load? I would also like to have him calculate with his slide-rule the size of a belt for the following conditions: 20.h.p. motor, 6 in. pulley, 1200 r.p.m., to drive a shaft 12 ft. away at 200. Would the same belt last as long if the drive were reversed,

that is, a shaft running at 200 r.p.m. driving a generator with 6 in. pulley at 1200? I would like also to ask Mr. Barth or any engineer present whether he would use the same size belt with the 6 in. pulley as a driver as with it as a driven, and with the same size of belt; and whether in this case it would last longer, other conditions being equal.

5 Anyone who has undertaken an investigation of the belt problem knows that it is almost impossible to keep conditions constant—humidity, oil in the belt, surface of pulley, etc., seem to change without notice and complicate the work.

6 I wish to congratulate Mr. Barth on his efforts to advance the theory of the transmission of power by leather belting, and to agree with Mr. Lewis in the conclusion of his paper presented in 1886, "That there is still need of more light on the subject."

Prof. C. H. Benjamin. I have been asked to contribute to the discussion of Mr. Barth's paper; technically, I am afraid I can not criticise it or add to it, for it leaves but little more to be said. Sentimentally, I can not but regret the gradual disappearance of our *terra incognita,* both geographical and mechanical. Time was when large areas on the map bore the encouraging legend "Unexplored Wilderness" or "Great American Desert" and left room for the free play of the imagination. Today you miss those fascinating areas and are tied down to realities.

2 Not many years ago, the grinding of a lathe tool was an interesting experiment, attended with much uncertainty, and the matter of feeds and speeds offered an alluring field for investigation. Mr. Taylor has spoiled all that for us and now our imagination is worked by slide-rule.

3 Time was when the possibilities of belting were vague in outline and when coefficient of friction, slack tension and belt creep were rather shadowy phantoms. It was pleasant then to speculate on what the belt would do and how long it would do it and the man with the longest memory had the advantage. But now, Mr. Lewis, Mr. Bird and Mr. Barth have taken all the romance out of it and another illusion succumbs to the deadly aim of the slide-rule.

4 Perhaps I take a malicious pleasure in noting that one or more factors of the problem are still out of harness and a trifle intangible. Our old friend, the coefficient of friction, is in hiding under the belt sporting with those other elusive fairies, modulus of elasticity and belt-creep. After all, what does it matter? Aside from the interesting

theoretical questions involved, what we need to know is, first, how wide a belt to use at a certain speed to transmit a certain power,—Mr. Taylor has answered this question. Second, how tight to lace or cement that belt that it may do the work for a reasonable time without relacing,—Mr. Barth has told us that.

5 I began experimenting on belts 25 years ago and have been at it more or less since. With a fixed pulley and a slipping belt, I found no difficulty in proving $\phi = 0.42$ after Rankine, but when I built a belt machine and tested belts under running conditions, ϕ lost all its constancy and might as well have been called x. Working backwards from the measured tension and using the old formula, I found ϕ to vary with the load, the speed, the kind of pulley, the age of the belt, the weather and the dominant political party—in fine, to be so mysterious and intangible a quantity as to be useless for practical purposes.

6 The sum of the tensions also varied in a manner that did not admit of rational explanation. And right here let me say that the reasons for Mr. Barth's assumption of constancy for $(t_1 + \frac{1}{2} t_2)$ are hardly clear to me. Why call that constant which is not constant? Why call anything constant except as it is shown to be so by measurement? This is not said in criticism but for the sake of information.

7 There is one aspect of the paper that deserves special attention and that is the recognition of the fact that a belt is an elastic connector with a variable length and variable tensions. Most writers on the subject have treated belting as if it were a non-extensible element which could be exactly represented on paper and whose behavior was capable of exact mathematical analysis. A belt in action is almost like a thing alive, squirming, lengthening, shortening, its tension changing back and forth with a variable modulus of elasticity and a lag in its changes due to its contact with the pulley and the short time intervals. A belt must be tested to be appreciated and theory must wait upon experiment.

8 I fully appreciate the value of Mr. Barth's analysis and can see that his methods will result in marked economies in establishments where many large belts are used and where conditions are pre-determined. In the smaller shop, where conditions vary, and in isolated cases with differing sorts of pulleys, differing kinds of belt, new and old, I feel that each case will have to be settled on its own merits. Until more experiments are recorded, the average machine-designer or millwright will have to be guided largely by his own judgment and experience in determining the width and tension of each belt. Let us have more experiments.

Mr. H. K. Hathaway.[1] To the scientist and machine-tool designer the value of Mr. Barth's paper will unquestionably be immediately apparent, but the writer feels that the paper does not represent with sufficient clearness features of the problem that are of inestimable value to the engineer concerned with running a shop. Assuming that the designer takes care of the sizes of belts required, and the speed at which they should be run, in accordance with the conclusions of such eminent authorities as Mr. Taylor, Mr. Barth, and Mr. Lewis a great deal is lost unless the shop-man properly cares for the maintenance of such belts. As Mr. Barth has pointed out, the care and maintenance of belting in the great majority of shops is done by rule of thumb, and left entirely to the judgment of the shop millwright or the workman operating the machine.

2 The efficiency of a belt-driven machine largely depends upon the tension of the belts being properly maintained at a point above the minimum initial tension at which they will transmit the power required. This point Mr. Barth has only slightly touched on, whereas the writer feels that this subject should have occupied a section fully as large as the body of the paper presented.

3 If a machine stands idle during working hours while the belt is being repaired or tightened it produces nothing during that time, and there is a distinct loss to the manufacturer. If a machine stands idle for one-half hour out of ten hours working time there is a loss of 5 per cent in the output of that machine and if in a shop having 100 machines, 10 machines out of the 100 lose one-half hour each day on account of repairs to belts it amounts to a loss of 0.5 per cent on the total output of the shop. This feature, however, is probably not so bad as the loss in output due to the machine belts being run so loose that they cannot begin to take the feeds, speeds, and depths of cut for which the machines are designed and that the tools will stand.

4 The writer has had considerable experience with the system of maintenance of belting mentioned in Par. 67 of Mr. Barth's paper, and will describe it briefly.

5 Almost every foreman or superintendent, in attempting to bring up the speeds of his machines to something like what he knows to be possible, has found that such attempts usually result in the belt's slipping or breaking, or the lacing giving out, and knows that where the care of belts is left to the man on the machine, only in a very few cases can the belts be depended upon to do the maximum

[1] Mr. H. K. Hathaway, The Tabor Mfg. Co., Philadelphia, Pa.

amount of work. If, therefore, the maximum feed, speed and depth of cut are to be prescribed and used, as is done by the aid of Mr. Barth's slide-rules under the Taylor system, it is essential that belts of the best quality and of the proper proportions be used, and that they be kept in first-class condition and at the proper tension, so that they can be relied upon to give the pull required. It is also necessary that all repairing, tightening, and inspection of belts be done outside of working hours that there may be no loss of output from interruption to manufacture. In order to accomplish these objects the following system has been evolved.

6 A record is kept for each belt in the shop on the form shown as Fig. 1, on which are given all standard data for each belt in question.

7 When a new belt is to be put on, or an old belt to be inspected or tightened, the special belt fixer's bench developed by Mr. Gulowsen is used, together with the belt-tension scales referred to by Mr. Barth. With this apparatus it is possible for one man to remove, tighten and replace almost any belt in from six to eighteen minutes. In putting on a new belt, or tightening an old one, the drums or pulleys on the belt bench are set by means of a steel tape to correspond with the distance over the actual pulleys, as previously determined, and shown on the belting record as "Length over Pulleys." A roll of belting, of the proper width and thickness, is next placed in the open drum, and passed through one pair of clamps of the belt scales around the drums or pulleys and through the other pair of clamps of the belt scales. The clamps are then tightened on the belt and the belt drawn up by means of the screws until the spring balances between the two pairs of clamps record the tension required, after which the belt is cut off so that the two ends will come together, and the belt is laced on a belt-lacing machine and put on its pulleys.

8 A memorandum, which also serves as the belt fixer's order and time card, giving him all necessary instruction, is then placed in what is called the "tickler," a portfolio having a compartment for each day of the year, under the date on which the belt will probably require re-tightening, and on that day it will be removed from the tickler, together with the memoranda for any other belts requiring attention, and sent to the belt fixer for attention during the noon hour and after quitting-time.

9 These belts are then removed from their pulleys, taken to the belt bench and tested to ascertain whether they require tightening; if the tension is found to have fallen to approximately the minimum,

BELTING DEPARTMENT............ BELT SYMBOL

Location....................................	Length over Pulleys........................	Max. Velocity.............
Purpose....................................	Width....................................	Min. Velocity..............
Kind....................................	Thickness....................................	Max. Tension.............. } ON EACH SPRING BALANCE
Maker's Name....................................	Cross Section in sq. in........................	Min. Tension.............. } ON EACH SPRING BALANCE
Date Put in Use....................................	How Fastened........................	Cost of Belt........................
Date Taken Out....................................	Belt Grease to be used........................	Cost of Maintenance........................
Life of Belt....................................	Belt Dressing to be used........................	Total Cost........................

Date Re-Tightened	Tension in Pounds Indicated by Each Spring Balance		Amount Taken Out	Date Tension Again Should be Taken	Date Cleaned and Greased	Date to be Cleaned and Greased Again	Date Dressing put on During Service	General Remarks about Work Done on Belt, Condition of Belt, etc.	Workman's Name	Man's Time Required to do Work	Cost of Work
	Before Tightening	After Tightening									

Fig. 1 Belt Record for Individual Belts

they are drawn up to the maximum tension as previously described, a piece is cut from one end, the belt is re-laced and put back in place and these facts are noted on the belt fixer's memorandum, which is then returned to the planning department, and entered on the belt record; and a new memorandum placed in the tickler under the

Out In		Order Number D L

Department
Day Rate.............................. Man's Time..............................

Max. Tension	Min. Tension	Belt Symbol	

Cleaned and Greased..........................Grease Used......................
Dressed While in Use ....Dressing Used......................
Amount Taken Out..........................Length Put In......................
Length of Splice..........................Cement Used......................

Tension in Lbs. Indicated by Each Spring Balance { Before Tightening.............................. After..............................

Workman's Name..Man's No.........

Entered in		
Pay Sheet	Cost Sheet	Belt Record

....

Day Work time note

Fig. 2 Belt Fixer's Order and Time Card

date on which the belt will again require attention. Notices for scraping, cleaning and greasing the belts at proper intervals are also placed in the tickler.

10 The length of time a belt will run before the tension will fall to the minimum at which it will pull all that is required, has been determined from experiments, and a belt seldom requires attention before the time set for re-tightening; when this does occur, however,

a belt-dressing which does not injure the belt, but which will enable it to pull properly until noon or the end of the day, is applied, and the memorandum is removed from the tickler and another placed under its next date for re-tightening.

11 The system described accomplishes four things of vital importance to economical production:

- *a* Freedom from interruption to production from having to repair belts during working hours, by having all belts systematically inspected and all breakdown and slippage anticipated and prevented before they occur.
- *b* Possibility of using the maximum feeds, speeds and depths of cuts at all times.
- *c* Increase in life of the belt owing to all belts being of the proper dimensions and properly laced and spliced and run at the proper tension.
- *d* Reduction of cost of maintenance to a minimum.

12 Mr. Barth's belting slide-rule is used in determining the dimensions of the belts, the maximum and minimum tensions. The writer can speak from experience of the great value of the belting slide-rule in solving the belting problems that confront the shop engineer, and while the mathematical features of Mr. Barth's paper are unquestionably interesting to many, the writer feels that, like himself, many will be glad to accept Mr. Barth's figures without question provided they can have the slide-rule.

13 It is a fact that in the average shop very few belts become unfit for use through legitimate wear, but rather through accidents or improper care. Where the care of the belts is left to the workman, the belts are usually far too loose, and when a belt slips it is less trouble for the workman to reduce his speed, feed, or depth of cut, or as a last resort to use rosin to make the belt pull. This use of rosin will ruin any belt in a very short time.

14 Very few machinists or even foremen know how to tighten or lace a belt properly, the amount to be taken out being usually guessed at, and a great deal of time is lost through the machine's standing idle while the cutting and trying is going on. The writer has seen a good machinist run a cone belt, which he had made too tight, on "cross cones," i. e., on steps not in line with each other, with the result that it twisted itself up like a corkscrew and was practically ruined.

15 Another cause of premature ruin of belts is improper lacing, the

ends not being cut square and the lacing on one side stretching more than the other, causing the belt to run crooked.

16 Cemented splices, when properly made, give the best results. Machine lacing, using a spiral wire lacing, while not so good as a cemented splice, is very satisfactory, however, and more convenient, and takes less time for putting on and taking off belts for the purpose of testing and tightening on the belt bench. A belt joined by a cemented splice must be tested and spliced in position, which is not so convenient as on the belt bench, especially in the case of overhead belts. Even where cemented splices are used the belt bench is convenient for cutting new belts, or re-tightening to a length giving the proper tension, and for repairs. Only one wire joint is used in any belt, splices being made if a section becomes damaged so that a new piece must be set in. The average belt if cared for under this system will last from six to eight years.

17 The tension on a new belt falls very rapidly, and our present practice is to tighten it after 24 hours, then in 48 hours, then in one week, then in two weeks, and so on doubling the length of intervals until it gets to three months; from this point we must ascertain by trial for each belt how much greater the intervals may be. This of course depends upon the severity of service the belt is called upon to perform as well as the quality of the belt.

Prof. L. P. Breckenridge. The American Society of Mechanical Engineers is to be congratulated upon this valuable and comprehensive contribution by Mr. Barth. He has done this work so well and presented it in a shape so usable, that I believe it will be, for many years, the standard of reference for those who are to decide upon the specific duties which belts of various widths shall be called upon to do. This paper again emphasizes the necessity for coöperation between the expert investigator and the mathematician who can analyze the results obtained. The specialized professions are becoming more and more dependent upon the help which each can give the other; engineering, in the future, will be more closely allied with the sciences of chemistry, physics, mathematics and mechanics, so that by the study of existing data principles may be established which the engineer cannot himself disclose.

Prof. Wm. S. Aldrich. The author has adopted a valuable and unique procedure in the preparation of technical papers; namely, to derive guidance for practical work from theory, and to submit that

theory to the rigorous requirements of extensive daily use before submitting it to the Society. It is needless to add that the theory which has stood that test is all the more invulnerable.

2 If appraisal is to be made of a given hypothesis or theory according to its utility, then surely Mr. Barth's theory of the transmission of power by leather belting has the highest commendation. It has worked, and that is the best test of the truth of new theories for the engineer. If machine tools are cutting metal today in the most intensive use of modern methods and driven by belting whose effective pulling power has been readily predetermined by slide-rules constructed according to Mr. Barth's theory of what leather belting ought to pull, then his deductions are reasonably secure. What are two or three of the most salient of these?

3 In the first plaçe, the academic discussion of the constancy of the sum of the belt tensions under all loads is finally set at rest. Now that we really know what is what, by the invaluable series of experiments referred to, the wonder is that this fallacy of the constancy of the sum of the belt tensions is so persistent in academic circles.

4 It was doubt of this position that led the writer to analyze for himself the experiments on belting then available, those of Mr. Wilfred Lewis and J. S. Bancroft, undertaken for Wm. Sellers & Co., and of Professor Lanza, of the Massachusetts Institute of Technology. Both of these were recorded in papers read before the Society, and published in Vol. 7 of the Transactions. It is remarkable that these classic experiments have been before the world thus long, and yet so little studied and respected, and, as far as the writer is aware, have not been superseded by experiments in their special field with more modern apparatus. Until they are superseded, Mr. Barth's conclusions must stand, a remarkable instance of the deductive reasoning by which it would seem that engineering progress must be made.

5 On the other hand, Mr. Barth has built up, in characteristic fashion, from theoretical considerations more or less influenced by a knowledge of the phenomena of belt-transmission, combined with the physical properties of belting, certain new and helpful relations that must govern in the future. Such is his "new theorem of the relations of the tension in a belt," that "Under any variation of the effective pull of a belt, the sum of the square roots of the tensions in the two strands remains constant, as against the old fallacious supposition that the sum of these tensions remains constant." (Appendix, Par. 26). Therefore,

$$\sqrt{T_1} + \sqrt{T_2} = 2\sqrt{T_0} \qquad (1)$$

6 Now, if we can obtain a similar relation for the difference of the square roots of the tensions, then we shall have at once, by the usual formula for the product of the sum and difference of two quantities, the difference of their squares; that is, in this case, the difference of the squares of the square roots of the tensions, which is the difference of the tensions, or the pulling power sought.

7 This much needed "difference of square roots of tensions has been indicated by Mr. Barth (Appendix Par. 14), "on the strength of the experiments made by Mr. Lewis and himself, namely, that within the limits of ordinary working tensions of a belt, the difference between the lengths of a belt at different tensions is proportional to the difference between the square roots of those tensions." We thus have,

$$L_1 - L_2 = K\left(\sqrt{T_1} - \sqrt{T_2}\right) \dots\dots\dots\dots\dots (2)$$

in which K is a constant, dependent upon the material of the belt, and determined by experiment on the belt.

8 Combining with Equation 1, we have, as already indicated

$$T_1 - T_2 = 2\sqrt{T_0}\,(L_1 - L_2)\,\frac{1}{K} \dots\dots\dots\dots\dots (3)$$

It seems to the writer that this might possibly be a helpful deduction, though it may be without much practical application; so that knowing the initial unit tension T_0 and the lengths of the belt under the tensions T_1 and T_2, together with the constant K, its pulling power $(T_1 - T_2)$ is known. It seems, therefore, necessary to know the difference in the lengths of the belt, due to differences in the belt tensions, that is, to the different driving powers under which it is expected to operate the belt, or in other words, to calibrate the belt-performance for this use.

9 It may be remarked, in passing, that the constant K is to be found from the experiments of Mr. Lewis, as analyzed by Mr. Barth (Appendix, Equation 3),

$$L_t = L\left(1 + \frac{\sqrt{t}}{864}\right) \dots\dots\dots\dots\dots (4)$$

in which L_t equals the length of belt under the unit tension t when its slack length is L. From this, by analogy with the above Equation 2, we have,

$$K = \frac{L}{864} \dots\dots\dots\dots\dots (5)$$

10 It will no doubt appear that the writer is still inclined to let the arc of contact and the coefficient of friction of belts take care of themselves, notwithstanding the keen discussion that has centered about the fourth conclusion in his paper, referred to by Mr. Barth; namely,

"(4) The ratio of the tensions of a belt-transmitting power cannot be calculated with any degree of accuracy by means of the well-known belt formula:

$$\frac{T_1}{T_2} = \theta^{f\theta} \qquad (6)$$

involving the arc of contact θ and the coefficient of friction f."

11 This relation is no doubt a guide and a help, indicating the way the ratios of belt tensions are most likely to be involved. But it certainly requires a radical modification to adapt it to any reliable use in predetermining the ratio of tensions for lacing up belts for given pulling power. Mr. Barth has wrought out these modifications with excellent results, judged by the adaptability of his slide rules, and the closeness of approximation to actual conditions (within the limits assigned) of the assumptions upon which they are based; namely (Par. 44), "that for the driving belt of a machine the *minimum initial tension* must be such that when the belt is doing the maximum amount of work intended, the *sum of the tensions on the tight side of the belt and one-half the tension on the slack side will equal 240 lb. per square inch of cross section for all belt speeds;* and that for a belt driving a countershaft, or any other belt inconvenient to get at for re-tightening or more readily made of liberal dimensions, this sum will equal 160 lb."

12 Here, then, is a definite acceptance of things as they are, and a straightforward assumption involving additive relations of belt tensions of leather belting, as it is made and used, and conformable to experience, rather than their ratios agreeable to theoretical formula, involving coefficient of friction and arc of contact. This latter relation (6) is as elusive as the traction-coefficient in railroad work; and engineers probably will have their own opinions about each until some genius can predetermine what coefficients of friction are to be expected in every instance, and so properly introduce the friction for dynamic conditions into a formula based entirely upon a consideration of statical relations.

The Author. In reading the unexpectedly numerous discussions of this paper, the author is pleased to note the general appreciation of it as a contribution to the literature of its kind, but regrets the assumption by two or three of the discussors that he considers the paper final in its application of the theories developed. All that is claimed is that he has taken practical advantage of the experimental data at his disposal, and has taken the pains to do mathematical justice to them, deriving therefrom excellent results in the scientific running of machine tools whose belts have been tightened and worked according to the rules thus established.

2 While the author feels guilty, therefore, of narrowing to a considerable extent the scope within which Professor Benjamin's imagination may still run rampant, so far as the behavior of a leather belt goes, he fully agrees that further experiments are needed in order to determine the coefficient of friction under all the variable conditions under which belts are called on to drive; and yet more, in order to settle conclusively whether the coefficient of friction is a function of the velocity of slip, as he has assumed, or of the percentage of slip, as indicated by Mr. Hamerstadt's study of numerous experiments at different belt speeds, though the latter seems contrary to the mechanical principles involved in the phenomenon of slip.

3 For the special benefit of Professor Bird, the writer will even say, that while all he knows about belting could probably be reduced to a pamphlet three times the size of his paper, a good-sized volume would probably be required to hold all he does not know but would like to know about belting, and a small library would be required to record all he does not care a straw to know about the subject.

4 But while the writer agrees with Mr. Hamerstadt as to the desirability of further experiments and will look forward to these with the keenest interest, he does not see the force of his argument about the necessary overload capacity of a high-speed belt, on a motor with an overload capacity; surely we need only make the belt big enough to take care of the overload as a normal load, and be satisfied to have it unnecessarily large for the rated capacity of the motor; just as a bridge intended for a light normal load must still be made strong enough for any anticipated occasional extra load. Trouble arises only when we do not know how to design a bridge properly, or when we get an occasional extra load which we have had no reason to anticipate.

5 Though the writer had not expected to be forced to express himself on the question of belt-drives *versus* electric motor drives, he

will say, in view of Mr. Robbins' remarks, that he believes that during the past decade hundreds of thousands of dollars, if not millions, have been more than wasted by the substitution of motor-drives for belt drives. Such a change has often been advantageous, of course, and is occasionally recommended to his clients by the writer: the trouble has been that the enormous investments of electrical manufacturing establishments have forced the electrical salesman more than any other to create a demand for his product, so that not only has he allowed his enthusiasm to run away with him, but he frequently has recommended his product against his own biased judgment; persuading the incompetent shop manager or superintendent to accept his product as a remedy for a small output that is in reality due to a complication of causes that could be cured only by the application of a number of remedial measures.

6 The writer believes, however, that a reaction against this indiscriminate electrification of machine shops has already set in, aside from the influence of the industrial depression, and that the electric drive will be installed, in the near future, only when conditions make it unquestionably more advantageous than the belt-drive.

7 As touched upon by Mr. Van Derhoef, the elastic properties of transmission-rope are probably similar to those of leather belts, and it seems to be in order for someone to ascertain them by the necessary experiments, and subsequently to apply this knowledge by use of the writer's methods.

8 The writer values Mr. Allen's statements of the advantages derived from the adoption of the Taylor system, as introduced by the author in the Yale & Towne Mfg. Co., plant where 4800 belts are thus taken care of. Mr. Allen, in conjunction with Messrs. Taylor, Hathaway and Waldron, has thus supplemented the scant attention paid in the paper to the aspect of the subject most practically important. The reason for this omission is that in his work with belting the writer has derived by far the greatest personal satisfaction from the solution of the mathematical problems involved, and he has been unable to eliminate entirely the personal interest.

9 It is not possible to answer here Mr. Cary's question as to how to estimate the horse-power required to drive each machine in a large plant, but the writer will be pleased to give him, and anybody else interested enough to pay a visit to Philadelphia, an idea of how it is done, by means of slide-rules especially constructed for the purpose.

10 As a further answer to Professor Bird's various statements and questions, the writer will only say that on a more careful reading of the paper, as well as the Appendix, and the copy of the Supplement sent him, he will find most of them answered. For instance, the most valuable mathematical developments in the Appendix and Supplement answer the question why the sum of the tensions of a belt increases with the load; and study of this will help him to formulate for himself an answer to his non-mathematical questioners.

11 As to the effect of crowning a small pulley, the writer heartily agrees with Professor Bird in a general way, though surprised to note with what confidence the latter estimates in the crudest and most superficial way the difference between the tensions in the middle and edge-fibers of a belt running over such a pulley. The writer would not attempt this without taking at least a week's vacation for the purpose, and so far has not felt warranted to do so, though well aware of the existence of the problem.

12 The writer is also highly pleased with the appreciation of his work expressed by Professor Breckenridge and Professor Aldrich, though he has not found the time to enter fully into the latter's second attempt to eliminate the coefficient of friction and the arc of contact in the solution of belt problems.

13 The author is sorry that the considerable trouble to which Mr. Nagle has gone to make comparisons with his own earlier formulae for the horse-power transmitted by leather belting, is based on a misunderstanding of the fundamental basis of the author's work.

14 As stated in the paper, the author bases his figures on a certain tension per square inch of belt, independent both of the strength of the belt itself and its thickness, and of the strength of the lacing, except that the latter must be in excess of the maximum tension brought to bear on a belt while delivering power. The author, therefore, makes no distinction between a single and a double belt, but merely considers the tension per square inch of section, as it has not been definitely proven that the coefficient of friction depends materially on the area of the surface presented by the belt against the pulley.

15 As Mr. Nagle somehow has assumed that the two horse-power curves in Fig. 3 are meant respectively for a single and a double belt, whereas they stand for something totally different, it unfortunately follows that the comparisons made by him of his own and the author's ideas as to what power a belt should be counted on to transmit, have completely miscarried.

16 Mr. Nagle says that we cannot decide upon the coefficient of

friction by formula. This is unquestionably so, but it is also true that, having roughly decided, by one means or another, what we wish to count on as the coefficient of friction at any one velocity of a belt, we may to great advantage make an empirical formula to represent a perfectly-graded change of this coefficient with the velocity; and only by so doing can we effect a mathematical solution of the belt problem that is an improvement on the unquestionably wrong assumption of a coefficient independent of the velocity of the belt, such as 0.42, originally recommended by Mr. Towne, or 0.28, recommended by the late Professor Ruleaux.

17 The author fully agrees with Mr. Nagle that "a new belt on an iron pulley may not have a coefficient of friction of as much as 0.25, while the same belt, well worn and well groomed, will give 0.65 in a clean, dry room;" and, more than that, knows that this elusive quantity will vary all the way from almost 0 to 1.50. However, just because the author is a practical and practicing engineer though very fond of a little pure mathematics in the handling of practical engineering problems, he has adopted *something* as a standard, this something being a variable lying happily between the great extremes, instead of being merely a single average between the extreme values.

18 The author is not at all disappointed because a perfectly new belt will not give the output required, at its minimum tension, without the resort to a temporary application of some good adhesion-producing belt-dressing; nor on the other hand, when a "well worn and groomed" belt at times is capable of giving the output required, at a little less initial tension than the one he aims at maintaining by the means more fully described in the discussions submitted by Mr. Allen and Mr. Hathaway.

19 Mr. Nagle also remarks that we rarely know the exact power to be transmitted except in the case of prime movers, which no doubt is true, so far as the work of most engineers is concerned. However, in the author's practice at least, the maximum output of every belt put up on any machine is known; simply because he personally sets the limit, and has means of seeing that the same is never exceeded.

20 Mr. Nagle refers to his paper read in 1881 as the first one to recognize the effect of centrifugal force in a belt. A correct formula, however, for the loss of effective tension in a belt, due to its centrifugal force, was given by Weisbach, at a much earlier date. This fact does not detract, of course, from the value of Mr. Nagle's paper, in which, probably for the first time, this matter was presented in a manner that made it readily available to the busy, practical engineer.

21 As regards Mr. Nagle's suggestion that the data have not been presented in a sufficiently handy form for the busy engineer, the author believes he has failed to appreciate the slide-rule illustrated in Fig. 5, which contains these data in a form which for handiness leaves tables and diagrams far behind.

ACCESSIONS TO THE LIBRARY

BOOKS

CATALOGUE OF TUFTS COLLEGE, 1908–1909. *Mass., College, 1909.* Gift of Tufts College.

DIE TURBINE, vol. 1-4. *M. Krayn, Berlin, 1904.* Gift of Edward C. Schmidt.

GUIDE TO SOUTH AFRICA, for the Use of Tourists, Sportsmen, Invalids and Settlers. Edition 15. *London, Sampson, Low, Marston & Co., Ltd., 1908.* Gift of Messrs. Donald Currie & Company.

RAILWAY SIGNAL ASSOCIATION. Digest of Proceedings, vols. 1–2, 4. *Bethlehem, Times Publishing Co., 1906–07.* Gift.

APPROACHES TO THE BLACKWELL'S ISLAND BRIDGE. New York City. Gift of Pennsylvania Steel Company.

PNEUMATIC CAISSONS, by T. K. THOMSON. Gift. Reprint from Construction, part I–II. *Nov. and Dec. 1908.*

PRESENT STATUS OF MILITARY AËRONAUTICS. By G. O. Squier. (Reprint from The Journal of The American Society of Mechanical Engineers). Gift of Society.

SOCIETY OF AUTOMOBILE ENGINEERS. Vol. IV, No. 1. Jan. 1909. *New York, 1909.* Gift of Society.

SOFTENING AND PURIFICATION OF FEED WATER FOR BOILERS. By J. C. Wm. Greth. Gift of Wm. B. Scaife & Sons Co.

TRANSACTIONS A. S. M. E. Vol. 9–26. Gift of H. L. Gantt.

WATER FOR ECONOMICAL STEAM GENERATION By J. C. Wm. Greth. Gift of Wm. B. Scaife & Sons Co.

WATER FOR THE LAUNDRY. By J. C. Wm. Greth. Gift of Wm. B. Scaife & Sons Co.

GIFT OF S. D. COLLETT

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIANA. 1st, 7th–10th. *Indianapolis, A. H. Conner, 1869, 1876–79.*

ANNUAL REPORT OF THE DEPARTMENT OF GEOLOGY AND NATURAL HISTORY OF INDIANA. 16th, 23d. *Indianapolis, W. B. Burford, 1889, 1899.*

ANNUAL REPORT OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES EMBRACING COLORADO, 1873. By F. V. Hayden, *Washington, U. S. Government, 1874.*

Altitudes Between Lake Superior and the Rocky Mountains. By Warren Upham. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 72.)

Analyses of Waters of the Yellowstone National Park. By F. A. Gooch and J. E. Whitfield. *Washington, Government, 1888.* (U. S. Geol. Surveys. Bulletin No. 47.)

Bear River Formation and its Characteristic Fauna. By C. A. White. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 128.)

Bibliography and Index of the Publications of the Geological Survey. By P. C. Warman. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 100.)

Bibliography of North American Geology for 1886. By N. H. Darton. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 44.)

Bibliography of North American Paleontology, 1888–1892. By C. R. Keyes. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 121.)

Bibliography of Paleozoic Crustacea from 1698 to 1889. By A. W. Vogdes. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 63.)

Boundaries of the United States and of the Several States and Territories. By Henry Gannett. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 13.)

Bulletin of the United States Geological and Geographical Survey of the Territories. Volume IV, No. 2. *Washington, Government, 1878.*

Cambrian Fauna of North America. By C. D. Walcott. *Washington, Government, 1884.* (U. S. Geol. Survey. Bulletin No. 10.)

Cambrian Rocks of Pennsylvania. By C. D. Walcott. *Washington, Government, 1896.* (U. S. Geol. Survey. Bulletin No. 134.)

Catalogue and Bibliography of North American Mesozoic Invertebrata. By C. B. Boyle. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 102.)

Catalogue of Geological Maps of America (North and South), 1752–1881. By Jules Marcou and J. B. Marcou. *Washington, Government, 1884.* (U. S. Geological Survey. Bulletin No. 7.)

Changes in River Courses in Washington Territory Due to Glaciation. By Bailey Willis. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 40.)

Classed and Annotated Bibliography of Fossil Insects. By S. H. Scudder. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 69.)

Colorado Formation and Its Invertebrate Fauna. By T. W. Stanton. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 106.)

Compressibility of Liquids. By Carl Barus. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 92.)

Constitution of the Silicates. By F. W. Clarke. *Washington, Government, 1895.* U. S. Geol. Survey. Bulletin No. 125.)

Contributions to the Cretaceous Paleontology of the Pacific Coast. By T. W. Stanton. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 133.)

Contributions to the Mineralogy of the Pacific Coast. By W. H. Melville and Waldemar Lindgren. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 61.)

Contributions to the Mineralogy of the Rocky Mountains. By William Cross and W. F. Hillebrand. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 20.)

Copper Smelting. By H. M. Howe. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 26.)

Correlation Papers, Archean and Algonkian. By C. R. Van Hise. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 86.)

Correlation Papers—Cambrian. By C. D. Walcott. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 81.)

Correlation Papers—Cretaceous. By C. A. White. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 82.)

Correlation Papers—Devonian and Carboniferous. By H. S. Williams. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 80.)

Correlation Papers—Eocene. By W. B. Clark. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 83.)

Correlation Papers—Neocene—By W. H. Dall and G. D. Harris. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 84.)

Correlation Papers—The Newark System. By I. C. Russell. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 85.)

Cotton Plant: Its History, Botany, Chemistry, Culture, Enemies, and Uses. *Washington, Government, 1896.* (U. S. Dept. of Agriculture. Bulletin No. 33.)

Crystallographic Study of the Thinolite of Lake Lahontan. By E. S. Dana. *Washington, Government, 1884.* (U. S. Geol. Survey. Bulletin No. 12.)

Development of Crystallization in the Igneous, Rocks of Washoe, Nevada. By Arnold Hague and J. P. Iddings. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 17.)

Devonian System of Eastern Pennsylvania and New York. By C. S. Prosser. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 120.)

Dictionary of Altitudes in the United States. By Henry Gannett. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 76.)

Dictionary of Geographic Positions in the United States. By Henry Gannett. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 123.)

Disseminated Lead Ores of Southeastern Missouri. By Arthur Winslow. *Washington, Government, 1896.* (U. S. Geol. Survey. Bulletin No. 132.)

Earthquakes in California in 1889, 1890–1894. *Washington, Government, 1890–1895.* (U. S. Geol. Survey. Bulletin Nos. 68, 95, 112, 129, 114.)

Eruptive and Sedimentary Rocks on Pigeon Point, Minnesota. By W. S. Bayley. *Washington, Government, 1893.* (U. S. Geological Survey. Bulletin No. 109.)

Flora of the Outlying Carboniferous Basins of Southwestern Missouri. By David White. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 98.)

Fossil Faunas of the Upper Devonian—The Genesee Section, N. Y. By H. S. Williams. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 41.)

Fossil Wood and Lignite of the Potomac Formation. By F. H. Knowlton. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 56.)

Form and Position of the Sea Level. By R. S. Woodward. *Washington Government, 1888.* (U. S. Geol. Survey. Bulletin No. 48.)

Formulas and Tables to Facilitate the Construction and Use of Maps. By R. S. Woodward. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 50.)

Fresh Water Invertebrates of the North American Jurassic. By C. A. White. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 29.)

Gabbros and Associated Hornblende Rocks. By G. H. Williams. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 28.)

Gabbros and Associated Rocks in Delaware. By F. D. Chester. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 59.)

Geographic Dictionary of Connecticut. By Henry Gannett. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 117.)

Geographic Dictionary of Massachusetts. By Henry Gannett. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 116.)

Geographic Dictionary of New Jersey. By Henry Gannett. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 118.)

Geographic Dictionary of Rhode Island. By Henry Gannett. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 115.)

Geological Reconnaissance in Central Washington. By I. C. Russell. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 108.)

Geological Reconnaissance in Northwest Wyoming. By G. H. Eldridge. *Washington, Government, 1894.* (U. S. Geol. Survey. Bulletin No. 119.)

Geological Reconnaissance in Southwestern Kansas. *Washington, Government, 1890.* (U. S. Geological Survey. Bulletin No. 57.)

Geology of the Big Stone Gap Coal Field of Virginia and Kentucky. By M. R. Campbell. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 111.)

Geology of Nantucket. By N. S. Shaler. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 53.)

Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana and Illinois. By G. F. Wright. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin, No. 58.)

Glaciation of the Yellowstone Valley North of the Park. By W. H. Weed. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 104.)

Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan. By G. H. Williams. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 62.)

Group of Volcanic Rocks from the Tewan Mountains, New Mexico. By J. P. Iddings. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 66.)

High Temperature Work in Igneous Fusion and Ebullition. By Carl Barus. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 103.)

Higher Devonian Faunas of Ontario County, New York. By J. M. Clarke. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 16.)

Index to the Known Fossil Insects of the World. By S. H. Scudder. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 71.)

Insect Fauna of the Rhode Island Coal Field. By S. H. Scudder. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 101.)

Invertebrate Fossils from the Pacific Coast. By C. A. White. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 51.)

Laramie and the Overlying Livingston Formation in Montana. By W. H. Weed. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 105.)

Late Volcanic Eruption in Northern California and Its Peculiar Lava. By J. S. Diller. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 79.)

Latitudes and Longitudes of Certain Points in Missouri, Kansas and New Mexico. By R. S. Woodward. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 49.)

Life and Public Services of Salmon Portland Chase. By J. W. Schuckers. *New York, D. Appleton & Co., 1874.*

Lignites of the Great Sioux Reservation. By Bailey Willis. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 21.)

List of Marine Mollusca Comprising the Quaternary Fossils and Recent Forms. By W. H. Dall. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 24.)

Maps of the Geological Survey of Indiana. *1869, 1872.*

Maps and Colored Section Referred to in the Report of the State Geologist of Indiana. *1869.*

Marine Eocene, Fresh Water Miocene and Other Fossil Mollusca of Western North America. By C. A. White. *Washington, Government, 1885.* (U. S. Geological Survey. Bulletin No. 18.)

Mechanism of Solid Viscosity. By Carl Barus. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 94.)

Mesozoic Echinodermata of the United States. By W. B. Clark. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 97.)

Message from the President of the United States to the Two Houses of Congress. *Washington, Government, 1880.*

Mineralogic Lexicon of Franklin, Hampshire and Hampden, Counties Mass. By B. K. Emerson. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 126.)

Minerals of North Carolina. By F. A. Genth. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 74.)

Mineral Springs of the United States. By A. C. Peale. *Washington Government, 1886.* (U. S. Geol. Survey. Bulletin No. 32.)

Nature and Origin of Deposits of Phosphate of Lime. By R. A. F. Penrose, Jr. *Washington, Government, 1888.* (U. S. Geol. Survey. Bulletin No. 46.)

New Cretaceous Fossils from California. By C. A. White. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 22.)

New York in the Revolution. By B. Fernow. *Albany, Weed, Parsons & Co., 1887.* (N. Y. State Archives, Volume I.)

Notes on the Geology of Northern California. By J. S. Diller. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin, No. 33.)

Notes on the Mesozoic and Cenozoic Paleontology of California. By C. A. White. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin, No. 15.)

Notes on the Stratigraphy of California. By G. F. Becker. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 19.)

Observations on the Junction Between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior. By R. D. Irving and T. C. Chamberlin. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 23.)

Paleozoic Section in the Vicinity of Three Forks, Montana. By A. C. Peale. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 110.)

Peridotite of Elliott County, Kentucky. By J. S. Diller. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 38.)

Physical Characteristics of the Iron Carburets. By Carl Barus and Vincent Strouhal. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 14.)

Physical Properties of the Iron Carburets, Third Paper. By Carl Barus and Vincent Strouhal. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 35.)

La Plata, the Argentine Confederation and Paraguay. By T. J. Page. *New York, Harper & Bros., 1859.*

Present Condition of Knowledge of the Geology of Texas. By R. T. Hill. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 45.)

Present Technical Condition of the Steel Industry of the United States. By Phineas Barnes. *Washington, Government, 1885.* (U. S. Geol. Survey. Bulletin No. 25.)

Quaternary and Recent Mollusca of the Great Basin. By R. E. Call. *Washington, Government, 1884.* (U. S. Geol. Survey. Bulletin No. 11.)

Record of North American Geology for 1887–1889, 1890 Inclusive. By N. H. Darton. *Washington, Government, 1891, '92.* (U. S. Geol. Survey. Bulletin Nos. 75, 91, 99.)

Relation of the Laramie Molluscan Fauna. By C. A. White. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 34.)

Relations of the Traps of the Newark System in the New Jersey Region By N. H. Darton. *Washington, Government, 1890.* (U. S. Geol. Survey. Bulletin No. 67.)

Report of a Geological Reconnaissance of Indiana Made During the Years 1859 and 1860. By Richard Owen. *Indianapolis, H. H. Dodd & Co., 1862.*

Reports on the Mineral Resources of the United States in 1868. *Washington, Government, 1868.*

Report of the U. S. Commissioner of Agriculture 1864 (2 cops.); 1866 1870, 1873–'75, 1877–'79. *Washington, Government, 1865, 1867, 1871 1874–'76, 1878–'80.*

Report of the Indiana State Board of Agriculture. 10th, 11th and 14th (2 cops.). *Indianapolis, 1868, '69 and 1872.*

Report of the Superintendent of Public Instruction for the State of Indiana. 18th. *Indianapolis, A. H. Conner, 1870.*

Report of Work Done in the Division of Chemistry During the Fiscal Years 1891–'92 and 1892–'93. By F. W. Clarke. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 113.)

Report of the Work Done in the Division of Chemistry and Physics Mainly During the Fiscal Years 1884–'85; 1885–'86; 1890–'91. *Washington, Government, 1886, 1887, '89–'92.* (U. S. Geol. Survey. Bulletin Nos. 27, 42, 55, 60, 64, 78, 90.)

Report of Progress of the Division of Hydrography for 1893 and 1894. By F. H. Newell. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 131.)

Report of Work Done in the Washington Laboratory, 1883–'84. *Washington, Government, 1884.* (U. S. Geol. Survey. Bulletin No. 9.)

Report on Astronomical Work of 1889 and 1890. By R. S. Woodward. *Washington, Government, 1890.* (U. S. Geol. Survey, Bulletin No. 70.)

Results of Primary Triangulation. By Henry Gannett. *Washington, Government 1894.* (U. S. Geol. Survey. Bulletin No. 122.)

Revision of American Fossil Cockroaches. By S. H. Scudder. *Washington, Government, 1895.* (U. S. Geol. Survey. Bulletin No. 124.)

Second Contribution to the Studies of Cambrian Faunas of North America. By C. D. Walcott. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 30.)

Secondary Enlargements of Mineral Fragments in Certain Rocks. By R. D. Irving and C. R. VanHise. *Washington, Government, 1884.* (U. S. Geol. Survey. Bulletin No. 8.)

Some Insects of Special Interest from Florissant, Colorado. By S. H. Scudder. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 93.)

Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio and West Virginia. By I. C. White. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 65.)

Subaërial Decay of Rocks and Origin of the Red Color of Certain Formations. By I. C. Russell. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 52.)

Subsidence of Fine Solid Particles in Liquids. By Carl Barus. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 36.)

Systematic Review of Our Present Knowledge of Fossil Insects Including Myriapods and Arachnids. By S. H. Scudder. *Washington, Government, 1886.* (U. S. Geol. Survey. Bulletin No. 31.)

Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee and Alabama Rivers. By E. A. Smith and L. C. Johnson. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 43.)

Texan Permian and Its Mesozoic Types of Fossils. By C. A. White. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 77.)

Thermo-Electric Measurement of High Temperatures. By Carl Barus. *Washington, Government, 1889.* (U. S. Geol. Survey. Bulletin No. 54.)

Trap Dikes of the Lake Champlain Region. By J. F. Kemp and V. F. Marsters. *Washington, Government, 1893.* (U. S. Geol. Survey. Bulletin No. 107.)

Trial of Andrew Johnson, Before the Senate of the United States on Impeachment by the House of Representatives for High Crimes and Misdemeanors. Volume I. *Washington, Government, 1868.*

Types of the Laramie Flora. By L. F. Ward. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 37.)

Upper Beaches and Deltas of the Glacial Lake Agassiz. By Warren Upham. *Washington, Government, 1887.* (U. S. Geol. Survey. Bulletin No. 39.)

Viscosity of Solids. By Carl Barus. *Washington, Government, 1891.* (U. S. Geol. Survey. Bulletin No. 73.)

Volume Thermodynamics of Liquids. By Carl Barus. *Washington, Government, 1892.* (U. S. Geol. Survey. Bulletin No. 96.)

EXCHANGES

Allgemeine Automobil Zeitung. Year 10, No. 4-date.

Annual Report of the Board of Regents of the Smithsonian Institution, 1907. *Washington, Government, 1908.*

Comparative Tests of Run-of-Mine and Briquetted Coal on Locomotives. By W. F. M. Goss. *Washington, Government, 1908.* (U. S. Geol. Survey. Bulletin No. 363.)

Industrial Progress. Vol. I, *Milwaukee, Wis., 1909.*

Railway Engineer, Vol. 30. *London, 1909.*

Railway News, *London,* Vol. 91, *Jan. 1909-date.*

Railway Times, *London,* Vol. 95. *1909-date.*

Report of the Librarian of Congress. 1908. *Washington, Government 1908.*

Study of Four Hundred Steaming Tests Made at the Fuel Testing Plant, St. Louis, Mo., in 1904, 1905, and 1906. By L. P. Breckenridge. *Washington, Government, 1907.* (U. S. Geol. Survey. Bulletin No. 325.)

Tests of Coal and Briquets as Fuel for House Heating Boilers. By D. T. Randall. *Washington, Government, 1908.* (U. S. Geol. Survey. Bulletin No. 366.)

Transactions of the Liverpool Engineering Society, Vol. 29. *Liverpool, Society, 1908.*

CATALOGUES

Burt Mfg. Co., Akron, Ohio, Burt Oil Filters Exhaust Heads and Ventilators. *Ohio, 1908.*

The Collins Wireless Bulletin. Collins Wireless Telephone Co., *Newark, 1909.*

Crane Company, *Chicago, Ill.* Valves and Fitting for Ammonia (catalogue No. 41).

Goldschmidt Thermit Company, 90 West St., *City.* Thermit Repairs.

Mirrlees, Bickerton and Day, Ltd. The "Mirrlees-Diesel" Oil Engine.

Wm. B. Scaife and Sons Company, 1st Ave., *Pittsburgh, Pa.* Water Purification for all Purposes.

Toledo Foundry and Machine Company, *Toledo, Ohio.* Victor Steam Shovels and Dipper Dredges.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

047 Instructorship in kinematics of machinery in Eastern college; incumbent to give lecture and recitation course and parallel drafting room course in the subject. Technical graduate who has shown excellent proficiency in the subject as a student and who has had at least one year of practical experience since graduation desired. New York State.

048 Assistant Professor in steam engine and boiler design; also some work in steam turbine design. Man is desired who has had experience in design and testing, preferably some teaching experience. Salary $1800 to $2000. Location New York State.

049 Wanted—An Assistant Superintendent in factory manufacturing—Location, Pennsylvania.

050 Expert on structural steel as applied to naval turrets or similar work. U. S. Government. Salary $1600 to $1800.

051 Electrical draftsman with experience in application of electrical machinery to naval turrets or similar work. U. S. Government. Salary $1600 to $1800.

052 Eight mechanical draftsmen, preferably experienced in design of ordnance. U. S. Government. Salary $1600 to $1800.

053 Ambitious young man, one with selling experience preferred, to handle in Philadelphia and neighboring towns, a machine involving the installation of complete power plants. A capable man can make this a profitable position.

054 By publisher in New York, young engineer to compile and edit engineering data. Preferably one with editorial experience who can read French and German. Permanent position.

MEN AVAILABLE

222 Machine shop superintendent or manager. Technical graduate. Experience covers from draftsman and salesman to works manager. All-round executive and mechanic. Successful in handling men and equipment for profitable output. Desires position as superintendent or manager, preferably with company employing 500 men or less.

223 Associate member, aged 30, who has specialized on fuel economy, and is carrying on a consulting practice with headquarters in New York, desires to become associated with other consulting engineer or firm of consulting engineers, either electrical or mechanical, with offices in New York City.

224 Associate desires to make a change. Varied drawing-room experience, including checking and charge of men. Would prefer work on heavy machinery and furnaces for rolling steel or tube mills.

225 Junior member; four years shop experience in design and construction of steam engines and general machinery, three years in charge of drafting departments; past five years designing and supervising construction of steam, gas and hydro-electric power plants; has also had experience in operation of electric plants.

226 Junior, technical graduate, American, 5 years experience in mechanical power station equipment, at present located in Germany, would consider position as European representative, preferably in Germany or England, for engineering or manufacturing company. Speaks German fluently.

227 Member of the Society, now assistant works manager of one of the large manufacturing establishments of the country, will undertake the betterment of existing manufacturing properties, or will develop new ones.

228 Member, with wide experience as executive officer in management of machine tool business, desires similar position. Location New England or New York.

229 Member, Stevens graduate, 25 years experience. Expert on highest grade of interchangeable manufacture. Competent as manager, superintendent, or chief engineer. Experience embraces the manufacture of automobiles, typesetting machinery, typewriters, firearms, etc.

230 Member, twenty years practical experience in designing, manufacturing and marketing special machinery (plant equipments). Broad acquaintance in the East. Will consider proposal from reliable manufacturer, to act as representative. Bank reference.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Thomas D. (Junior, 1906), Werner and Pfleiderer, and *for mail,* 732 Jefferson Ave., Saginaw, Mich.

AHRNKE, H. P. (Junior, 1902), Pa. Tunnel and Terminal R. R. Co., Office of Ch. Engr. of Elec. Traction, 8–10 Bridge St., New York, N. Y.

ALLEN, George L., Jr. (Junior, 1906), Iloilo, Philippine Islands.

ANDERSON, Harry Warfield (Associate, 1907), V. P., W. E. Austin Co., Mgr., Auto Dept., Atlanta Buggy Co., 1228 Candler Bldg., and *for mail,* No. 6, Lenox Apt., 31 Porter Pl., Atlanta, Ga.

BARROWS, Lee Earle (Junior, 1908), care of Y. M. C. A., Nelsonville, O.

BATCHELOR, Charles (1880), 33 W. 25th St., New York, N. Y.

BLACK, Edward S. (1903), 35 Wade Bldg., Cleveland, O.

BOGARDUS, Henry A. (Associate, 1907), Henry A. Bogardus & Co., 178 E. Huron St., Chicago, Ill.

BRINTON, Willard C. (Junior, 1907), Industrial Engr., Westinghouse Elec. and Mfg. Co., East Pittsburg, and *for mail,* 611 Whitney Ave., Wilkinsburg Sta., Pittsburg, Pa.

CALDWELL, John A. (1907), 90 West St., New York, N. Y., and *for mail,* 55 Walnut St., Montclair, N. J.

CHAMBERLAIN, George E. (1907), 1614 Fisher Bldg., Chicago, Ill.

CHAPMAN, David Albert (Junior, 1908), Supt. of Estate of E. S. Converse Co., 101 Milk St., Boston, and *for mail,* 163 Grover Ave., Winthrop Highlands, Boston, Mass.

CHRISTIE, Alexander G. (Associate, 1907), Research Asst. in Steam Engrg., Univ. of Wisconsin, and *for mail,* 1713 Monroe St., Madison, Wis.

CHURCHILL, Chas. O. (1906), The Georgian Mfg. Co., Binghamton, N. Y.

COMLY, Geo. N. (1880), 1816 W. Genesee St., Syracuse, N. Y.

COON, Thurlow Emmett (Junior, 1908), 1443 Washtenaw Ave., Ann Arbor, Mich.

CRANE, William Edward (1887), 420 Willow St., Waterbury, Conn.

DARLINGTON, Philip J. (1904), The Roto Co., P. O. Box 1043, Hartford, Conn.

DE CAZNOVE, Louis A., Jr. (Junior, 1905), Mech. Engr. of Constr. Dept., E. I. Du Pont De Nemours Powder Co., and *for mail,* The Wilmington, Delaware Ave., Wilmington, Del.

DYER, Robt. M. (1892; 1904), V. P. and Treas., Puget Sound Bridge and Dredging Co., 432–41 Central Bldg., and 420 13th Ave., N., Seattle, Wash.

ESTES, William Wood (1891;1904), Designer, Taft-Pierce Co., Woonsocket, and *for mail,* 245 Waterman St., Providence, R. I.

FLORY, Burton P. (1906), Supt. M. P., Ontario & Western Ry. Co., Middletown, N. Y.

FOX, Royal E., Jr. (Junior, 1901), V. P., The Engineer Co., 30 Church St., Room 1180, and Irving Arms, 222 Riverside Drive, New York, N. Y.

GANNETT, Herbert I. (Junior, 1900), V. P. and Genl. Mgr., Monarch Acetylene Co., 66–70 Exchange St., and 113 Summit Ave., Buffalo, N. Y.

GAZZAM, Joseph P. (1902), Life Member, 5027 Westminster Pl., St. Louis, Mo.

GODFREY, Eli S. (1891), Tannersville, N. Y.

GORDON, Fred. W. (1880), Gladstone, 11th and Pine Sts., Philadelphia, Pa.

GRAVER, Alexander M. (Junior, 1908), Mech. Engr., Wm. Graver Tank Wks., East Chicago. Ind., and 7211 Yale Ave., Chicago, Ill.

GRAY, John Lamont (Associate, 1904), Gray Bros., Engrs. and Shipbuilders, and *for mail*, care of Ardlamont, 9 Esplanade, Williamstown, Melbourne, Victoria, Australia.

HANEY, James Briggs (Junior, 1905), U. S. Engr. Office, McCandless Bldg., Honolulu, Hawaii.

HANSELL, William H. (1908), Member firm of Edward Smith Co., Cons. Engrs., 605 Provident Bldg., and *for mail*, 4420 Sansom St., Philadelphia, Pa.

HAUGHTON, Frank A. (1903), 243 Jamaica Ave., Flushing, L. I., N. Y.

HAYWARD, Henry S., Jr. (1900; 1907), 60 North Ave., Elizabeth, N. J.

HENES, Louis G. (Junior, 1903), Key Route Hotel, Oakland, Cal.

HERBERT, Charles G. (1900), Solvay Process Co., Syracuse, N. Y.

HIRT, Louis Joseph (1894), Mech. Engr., Broad Exchange Bldg., 25 Broad St., New York, and *for mail*, 34 Morsemere Pl., Yonkers, N. Y.

HUMPHREYS, Alex. C. (1884), Manager, 1907–1910, Life Member; Pres., Stevens Inst. of Tech., Hoboken, N. J., Pres., Buffalo Gas Co., and Senior Member of Humphreys & Glasgow, Incorp., 165 Broadway, New York, N. Y.

JACKSON, Roscoe B. (Junior, 1904), 1091 Champlain St., Detroit, Mich.

JAKOBSSON, Herman G. (1907), Engrg. Dept., Midvale Steel Co., Philadelphia, Pa.

LARSON, Charles J. (1907), Ch. Engr., Union Elec. Co., and *for mail*, 1058 Locust St., Dubuque, Ia.

LEEPER, Ralph W. (Junior, 1908), 304 Clinton St., Schenectady, N. Y.

LILLIE, Grant W. (Junior, 1901), Mech. Engr., St. Louis & San Francisco R R., and *for mail*, 1120 Summit St., Springfield, Mo.

LUCAS, Henry van Noye, Jr. (Junior, 1905), present address unknown.

LUNGER, Waldo G. (Junior, 1901), 637 Hinman Ave., Evanston, Ill.

McKIEVER, Wm. Henry (1900), Everett Bldg., Union Sq. N., and *for mail*, 120 Central Park S., New York, N. Y.

NEUHAUS, Fritz A. E. (1898;1906), Ch. Engr. and Genl. Supt., A. Bosrig, Tegel Berlin, and Olivaerplatz 7, Charlottenburg, Germany.

PALMER, Virgil Maro (Junior, 1905), Selden Motor Vehicle Co., Rochester, N. Y.

PERRIGO, Oscar Eugene (1904), Cons. Mech. Engr. and Pres., Modern Systems Cor. School, 6 Beacon St., Boston, and 151 Lynnfield St., Peabody, Mass.

PERRY, Samuel B. (Junior, 1895), 72 William St., New York, and Hollis, L. I., N. Y.

PINGER, Geo. C. (Junior, 1907), The Wm. Tod Co., and *for mail*, 239 Spring St., Youngstown, O.

POWELL, E. Burnley (Junior, 1904), Stone & Webster Engrg. Corp., 147 Milk St., Boston, Mass.

PRATT, Charles Richardson (1896), Cons. Engr., 1123 Broadway, New York, N. Y., and 39 Gates Ave., Montclair, N. J.

RIDDLE, Howard Sterling (1905), Wks. Engr., The Jeffrey Mfg. Co., and *for mail*, 904 Neil Ave., Columbus, O.

ROBERTS, Edmund W. (1904), Mech. Engr., V. P. and Genl. Mgr., The Roberts Motor Co., Sandusky, O.

ROSE, William Holliday (Junior, 1901), 220 Broadway, New York, N. Y.

ROSS, Taylor W. (Junior, 1895), Asst. Supt. of Hull Constr., Newport News Ship-Building and Dry Dock Co., and *for mail*, 3112 West Ave., Newport News, Va.

RUST, Edwin Gray (1901), Treas., Sheffield Coal and Iron Co., Sheffield, Ala.

SARENGAPANI, T. S. (Junior, 1903), Head Draftsman, P. W. D., Bezwada, and *for mail*, Karantattamkudy, Tanjore, Madras, India.

SMITH, William E. (Junior, 1908), 518 Olive St., Scranton, Pa.

TALCOTT, R. Barnard (1907), Florence Court, Washington, D. C.

TRACY, Theron H. (1902), Pres., Tracy-Devereaux Co., 211–15 Kerckhoff Bldg., Los Angeles, Cal.

VAN VALKENBURGH, Ralph D. (1901; Associate, 1905), Ch. Engr., H. W. Caldwell & Son Co., Wes ern Ave., 17–18th Sts., and *for mail*, 1088 Millard Ave., Chicago, Ill.

WEAR, Burt C. (Junior, 1905), Draftsman, Engrg. Dept., Republic Iron and Steel Co., and *for mail*, 272 Arlington St., Youngstown, O.

WILDER, Sylvanus Wells (Junior, 1907), Supt., Dolphin Jute Mills, and *for mail*, 283 Ellison St., Paterson, N. J.

WILSON, Clarence C. (Junior, 1900), Cons. Engr., 22 First St., San Francisco, Cal.

ZIMMERMAN, Oliver B. (1905), Ch. Draftsman, M. Rumely Co., La Porte, Ind.

NEW MEMBERS

ALDEN, Herbert W. (1908), Mech. Engr., Timken Roller Bearing Axle Co., Canton, O.

BANNON, Leo Matthew (Junior, 1908), Asst. Supt., Union Bleaching and Finishing Co., Greenville, S. C.

BIXBY, William P. (Junior, 1908), Erie Railroad Co., and *for mail*, P. O. Box 364, Meadville, Pa.

CHESTER, Chas. Porter (Associate, 1908), Supt., The Morenci Water Co., Morenci, Ariz.

CHURCH, Elihu C. (Junior, 1908), Lecturer, Dept. of C. E., Columbia Univ., and *for mail*, 4 E. 130th St., New York, N. Y.

CRAIG, Charles H., Jr. (1908), Asst. Supt., Am. Steam Gage and Valve Mfg. Co., 208 Camden St., Boston, and *for mail*, Needham, Mass.

DE VED, Horace W. (Junior, 1908), Asst. to Engr., Westchester Lighting Co., Mt. Vernon, N. Y.

DULL, Raymond Wm. (1908), Ch. Engr., Stephens-Adamson Mfg. Co., Aurora, Ill.

DUNHAM, George W. (1908), Ch. Engr., Olds Motor Wks., and 738 Ionia St. W., Lansing, Mich.

DYER, Robert A., Jr. (1908), Asst. Genl. Mgr., Rochester, Syracuse & Eastern R. R. Co., and *for mail*, 2 Sheridan St., Auburn, N. Y.

ENGLISH, Harry K. (Associate, 1908), Box 688, Gary, Ind.

KEIL, Gustave B. (1908), M. M., Mills Novelty Co., Mills Bldg., and *for mail*, 2340 N. Paulina St., Chicago, Ill.

MEES, Curtis A. (Associate, 1908), Designing Engr., Southern Power Co., Charlotte, N. C.

NEELY, Frank Henry (Junior, 1908), Westinghouse Elec. and Mfg. Co., and *for mail*, 435 Ross Ave., Wilkinsburg, Pa.

PARKER, Levin S. (1908), Mech. Engr., Atlantic Gulf and Pacific Co., 2407 Park Row Bldg., New York, N. Y.

PAUL, Charles Edward (1908), Assoc. Prof. of Mechanics, Armour Inst. of Tech., and *for mail*, 6355 Ingleside Ave., Chicago, Ill.

PULMAN, Thomas Chas. (1908), 10 Clive St., Calcutta, India.

ROBINSON, Arthur L. (1908), Elec. Engr., Isthmian Canal Com., Culebra, Canal Zone, Central America.

SATTERFIELD, Howard E. (Associate, 1908), The N. C. College of Agriculture and Mechanic Arts, West Raleigh, N. C.

SCOTT, Arthur Curtis (1908), Prof. of Elec. Engrg., Univ. of Texas, Austin, Texas.

SPENCER, Frank C. (Associate, 1908), Mech. and Constructing Engr., 7135 Eggleston Ave., Chicago, Ill.

THOMAS, Carl C. (1908), Prof. of Mech. Engrg., Univ. of Wisconsin, Madison, Wis.

THOMPSON, Byron Lyman (Associate, 1908), Asst. Mgr., Bi-Carbonate Dept., Solvay Process Co., and *for mail*, 212 Erie St., Syracuse, N. Y.

TOMLINSON, Charles E. (Associate, 1908), Smith Premier Typewriter Co., Syracuse, N. Y.

VOIGHT, Henry Gustave (1908), Supt. of Design and Constr., Russell & Erwin Mfg. Co., and *for mail*, P. O. Box 406, New Britain, Conn.

WALLACE, Jacob H. (Associate, 1908), Instr. in drawing, Univ. of Colo., and *for mail*, 1313 7th St., Boulder, Colo.

WALLICHS, Adolph O. (1908), Prof., Technische Hochschule, and *for mail* Wizze-Allee 65, Aachen, Germany.

WINSHIP, Walter E. (1908), Advisory Engr., Gould Coupler Co., Sales Engr., Gould Storage Battery Co., and *for mail*, 82 W. Washington Pl., New York, N. Y.

PROMOTIONS

COX, Frank G. (1905; 1908), Engr. Otis Elevator Co., 17 Battery Pl., New York, N. Y.

LIBBEY, Joseph Harold (1901; 1904; 1908), Mech. and Elec. Engr., Stone & Webster Engrg. Corp., 147 Milk St., Boston, and 14 Parsons St., West Newton, Mass.

OHLE, Ernest L. (1906; 1908), Washington Univ., St. Louis, Mo.

O'NEIL, Frederick Wm. (1901; 1908), N. Y. Mgr., Nordberg Mfg. Co., Room 1009, 42 Broadway, New York, and 260 Pelham Rd., New Rochelle, N. Y.

WILLCOX, George B. (1895; 1908), Secy. Treas., and Genl. Mgr., Willcox Engrg. Co., 502 Eddy Bldg., and 1413 Genesee Ave., Saginaw, Mich.

RESIGNATIONS

FOUCARD, Marcel L.
NORTHRUP, Lewis M.
WHITLOCK, R. H.

DEATHS

ALLEN, Walter M.
CHICKERING, Kenton
GRAY, Thomas
HUYETTE, William S.

Gas Power Section

CHANGES OF ADDRESS

COMLY, Geo. N. (1908), 1816 W. Genesee St., Syracuse, N. Y.
LANE, J. S. (1908), 50 Church St., New York, N. Y.
ZIMMERMAN, Oliver B. (1908), Ch. Draftsman, M. Rumely Co., La Porte, Ind.

NEW MEMBERS

BAKER, John A. (Affiliate, 1908), Traveling Engr., Power and Mining Mchy. Co., 115 Broadway, New York, N. Y.

BARNABY, Charles W. (1908), 309 Broadway, New York, N. Y.

BUMP, Milan Raynard (Affiliate, 1908), Secy., Doherty Operating Co., 60 Wall St., New York, N. Y.

COOK, Wm. Pierson, Jr. (Affiliate, 1908), Salesman, Buick Motor Co., 1111 Dean St., Brooklyn, N. Y.

CORMACK, George, Jr. (Affiliate, 1908), V. P. and Designer, Rockford Eng. Wks., Rockford, Ill.

ENNIS, Wm. Duane (1908), Prof. Mech. Engrg., Polytechnic Inst., Brooklyn, N. Y.

GILLETTE, Ralph P. (Affiliate, 1908), Mgr. Mech. Sales and Secy., Minneapolis Steel and Mchy. Co., Minneapolis, Minn.

HANSON, George (Affiliate, 1908), Supt., Charter Gas Eng. Co., Sterling, Ill.

HASBROUCK, Stephen A. (Affiliate, 1908), Mech. Engr., 177 Willetts ave., New London, Conn.

HOPCROFT, Ernest Bigly (Affiliate, 1908), 511 Insurance Bldg., Rochester, N. Y.

LATHROP, Jay Cowden (Affiliate, 1908), Cons. Engr., 717 Terminal Bldg., New York, N. Y.

LOOMIS, Malcolm F. (Affiliate, 1908), Sales Mgr. and Supt., Alamo Mfg. Co., Hillsdale, Mich.

MAIBAUM, Jerome (Affiliate, 1908), Leading Elec. Draftsman, N. Y. Edison Co., 55 Duane St., and 1052 Grant Ave., New York, N. Y.

MATTHEWS, Fred E. (1908), Room 901, 90 West St., New York, N. Y.

MAYERS, J. Alex (Affiliate, 1908), Gas Engr., 56 Pine St., New York, N. Y.

MONAHAN, Louis J. (Affiliate, 1908), V. P., Supt. and Mech. Engr., Termaat & Monahan Co., 270 Washington St., Oshkosh, Wis.

MORRISON, William S. (Affiliate, 1908), Leading Mech. Draftsman, N. Y. Edison Co., 55 Duane St., New York, N. Y.

NILSON, Lars G. (Affiliate, 1908), Ch. Engr., Strang Gas-Elec. Car Co., and *for mail,* 108 13th St., Hoboken, N. J.

OESTERREICHER, Sandor Ignatius (Affiliate, 1908), Elec. Draftsman, 342 High St., Newark, N. J.

PARKER, John Castlereagh (1908), Mech. and Elec. Engr., Rochester Ry. and Light Co., Rochester, N. Y.

PLATTS, C. Arthur (Affiliate, 1908), Ch. Engr. Producer Gas Sta., B. E. Ry. Co., 399 Salem St., Medford, Mass.

SANDELL, Sixten O. (Affiliate, 1908), Draftsman, N. Y. Edison Co., 55 Duane St, New York, N. Y.

SEAGER, James B. (1908), Genl. Mgr., Olds Gas Power Co., Lansing, Mich.

SERGEANT, Chas. H. (1908), Mech. Engr., 4 Manhattan Ave., New York, N. Y.

SKEHAN, Eugene A. (Affiliate, 1908), Leading Elec. Draftsman, N. Y. Edison Co., 55 Duane St., New York, N. Y.

SMITH, Bronson H. (Affiliate, 1908), Mech. Engr., Westinghouse, Church, Kerr & Co., New York, and *for mail,* 450 E. 21st St., Brooklyn, N. Y.

SNYDER, William E. (1908), Mech. Engr., Am. Steel and Wire Co., Frick Bldg., Pittsburg, and *for mail,* Denslow Apts., California Ave., Allegheny, Pa.

SPARROW, Ernest P. (1908), B. F. Sturtevant Co., Hyde Park, and *for mail,* 18 Gleason St., New Dorchester, Mass.

STETSON, George R. (1908), Pres. and Genl. Mgr., New Bedford Gas and Edison Light Co., 125 Middle St., and 7 Anthony St., New Bedford, Mass.

YOUNG, Nelson J. (Affiliate, 1908), N. Y. Edison Co., 55 Duane St., New York, N. Y.

COMING MEETINGS

AERONAUTIC SOCIETY
March 10, etc., evenings, weekly meetings, Automobile Club of America, W. 54th St., New York. Secy., Wilbur R. Kimball.

AMERICAN GAS POWER SOCIETY
April 27, quarterly meeting, Minneapolis, Minn. Secy., R. P. Gillette.

AMERICAN GEOGRAPHICAL SOCIETY
March 23, 29 W. 39th St., New York, 8 p.m. Paper: Across Widest Africa, A. H. S. Landor. Clerk, H. D. Ralph.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
March 12, April 9, 33 W. 39th St., New York, 8 p.m. Secy., R. W. Pope.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
March 26, monthly meeting, Toronto Section. Secy. *pro tem.*, W. H. Eisenheis, 1207 Traders' Bank Bldg.

AMERICAN SOCIETY OF CIVIL ENGINEERS
March 17, April 7, 220 W. 57th St., New York. Secy., C. W. Hunt.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
March, 24, joint meeting on Conservation of Natural Resources, 29 W. 39th St., New York, 8 p.m. Secy., Calvin W. Rice.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION
March 16–18, annual convention, Auditorium Hotel, Chicago, Ill. Secy., E. H. Fritch, 962 Monadnock Blk.

ARCHITECTURAL INSTITUTE OF CANADA
April 6, Special General Meeting, Toronto, Ont. Secy., Alcide Chaussé, Montreal, Que.

ASSOCIATION OF ELECTRIC LIGHTING ENGINEERS OF NEW ENGLAND
March 17, annual meeting, Boston, Mass.

BLUE ROOM ENGINEERING SOCIETY
April 1, 29 West 39th St., New York. Secy., W. D. Sprague.

BOSTON SOCIETY OF ARCHITECTS
April 6. Secy., Edwin J. Lewis, 9 Park St.

BOSTON SOCIETY OF CIVIL ENGINEERS
March 17, annual meeting, Tremont Temple. Secy., S. E. Tinkham, City Hall.

BROOKLYN ENGINEERS' CLUB
March 11, 197 Montague St., Brooklyn, N. Y. Paper: Fire Hazard and Fire Protection in the U. S., Hugh T. Wreaks. Secy., J. Strachan.

CANADIAN CEMENT AND CONCRETE ASSOCIATION
March 1–6, Convention, Toronto, Ont. Secy., A. E. Uren, 62 Church St.

CANADIAN FREIGHT ASSOCIATION
April 9, annual meeting. Secy., T. Marshall, Toronto, Ont.

CANADIAN MINING INSTITUTE

March 3–5, annual meeting, Windsor Hotel, Montreal, Que. Secy., H. Mortimer-Lamb. Windsor Hotel.

CANADIAN RAILWAY CLUB

April 6, Windsor Hotel, Montreal, Que., 8 p.m. Secy., Jas. Powell, St. Lambert, Montreal.

CANADIAN SOCIETY OF CIVIL ENGINEERS

March 12, General Sectional Meeting; March 19, electrical section; March 26, mechanical section; April 2, mining section. 413 Dorchester St. W., Montreal, Que. Secy., Prof. C. H. McLeod.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Manitoba Branch

March 4, April 8, monthly meetings, University of Manitoba. Paper for March: Transcontinental Railway from Moncton to Winnipeg, S. R. Poulin. Secy., E. Brydone Jack.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Toronto Branch

March 25, regular meeting, 96 King St. W. Secy., T. C. Irving, Jr.

CAR FOREMEN'S ASSOCIATION OF CHICAGO

April 12. Secy., Aaron Kline, 326 N. 50th St.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

April 13, Cincinnati, Ill., 11 a.m.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

March 11, Toledo, O. Secy., H. M. Ellert.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA

March 16, Rossin House, Toronto, Ont. Secy., C. L. Worth, Room 409, Union Sta.

CENTRAL RAILWAY CLUB

March 12, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Paper: The Use of Steel in Passenger Car Construction, J. McE. Ames. Secy., H. D. Vought, 95 Liberty St., N. Y.

CLEVELAND ENGINEERING SOCIETY

March 9, monthly meeting, Caxton Building. Paper: Niagara Falls Hydraulic Power Co., G. R. Shepherd. Secy., Joe C. Beardsley.

COLORADO SCIENTIFIC SOCIETY

April 3, monthly meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EASTERN ASSOCIATION CAR SERVICE OFFICERS OF NEW YORK

March 25.

ENGINEERING ASSOCIATION OF THE SOUTH

March 16, monthly meeting, Nashville Section, Carnegie Library Bldg. Section Secy., H. H. Trabue, Berry Blk., Nashville.

ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA

April 6, monthly meeting, Iowa City, Ia. Secy., Dean Wm. G. Raymond.

ENGINEERS' AND ARCHITECTS' CLUB

March 15, 303 Norton Bldg., Louisville, Ky. Secy., Pierce Butler.

ENGINEERS' CLUB OF BALTIMORE

April 3, monthly meeting. Secy., R. K. Compton, City Hall.

ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA

April 6, monthly meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher.

ENGINEERS' CLUB OF CINCINNATI
March 18, 25 E. 8th St. Secy., E. A. Gast, P. O. Box 333.

ENGINEERS' CLUB OF PHILADELPHIA
March 20, April 3, 10, 1317 Spruce St. Secy., H. G. Perring.

ENGINEERS' CLUB OF TORONTO
March 11, etc., weekly, 96 King St., W., Toronto, Ont. Secy., R. B. Wolsey.

ENGINEERS' SOCIETY OF MILWAUKEE
March 10, 456 Broadway, Milwaukee, Wis. Secy., W. Fay Martin.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA
March 16, regular meeting; April 6, Sectional Meeting. Secy., E. K. Hiles.

EXPLORERS' CLUB
April 2, 29 West 39th St., New York. Secy., H. C. Walsh.

FRANKLIN INSTITUTE
March 11, Philadelphia, Pa. Paper: Power Factor and Commutation Conditions in Singlephase Series Motors, A. S. McAllister.

GENERAL MANAGERS ASSOCIATION OF CHICAGO
March 18.

GENERAL SUPERINTENDENTS' ASSOCIATION OF CHICAGO
March 17. Secy., H. D. Judson, 209 Adams St.

ILLUMINATING ENGINEERING SOCIETY
March 11, April 8, monthly meetings, New York Section, 29 W. 39th St., 8 p.m. Secy., P. S. Millar.

INTERNATIONAL MASTER BOILER-MAKERS' ASSOCIATION
April 27–30, Convention, Hotel Sealbach, Louisville, Ky. Secy., H. D. Vought, 95 Liberty St., New York. Standardizing Blue Prints for Building Boilers; Boiler Explosions; Best Method of Applying Flues, Best Method for Caring for Flues While Engine is on the Road and at Terminals and Best Tools for Same; Flexible Staybolts Compared with Rigid Bolts; Best Method of Applying and Testing Same; Steel vs. Iron Flues, What Advantage and What Success in Welding Them; Best Method of Applying Arch Brick; Standardizing of Shop Tools; Standardizing of Pipe Flanges for Boilers and Templets for Drilling Same; Which is the long way of the Sheet; Best Method of Staying the Front Portion of Crown Sheet on Radial Top Boiler to Prevent Cracking of Flue Sheet in Top Flange; Rules and Formulas; Senate Bill.

IOWA ELECTRICAL ASSOCIATION
April 21, 22, Cedar Rapids. Secy., W. N. Keiser, Des Moines.

IOWA RAILWAY CLUB
March 12, April 9, Des Moines.

LOUISIANA ENGINEERING SOCIETY
April 12, 323 Hibernia Bldg., New Orleans. Secy., L. C. Datz.

MASSACHUSETTS STREET RAILWAY ASSOCIATION
March 10, Boston. Secy., Charles S. Clark, 70 Kilby St.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK
March 24, 29 W. 39th St., 8:15 p.m. Secy., C. D. Pollock.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS
April 7, New York. Secy., C. C. Hildebrand, 7 E. 42d St.

NEW ENGLAND RAILROAD CLUB
March 9, annual meeting, Young's Hotel, Boston, Mass., 8 p. m. Secy., Geo. H. Frazier, 10 Oliver St. Paper: The Railroad Club; its Worth, A. W. Martin.

NEW ENGLAND STREET RAILWAY CLUB

March 25, annual meeting, American House, Boston, Mass. Secy., John J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION

March 10, regular meeting. Secy., Willard Kent, Tremont Temple, Boston, Mass.

NEW YORK RAILROAD CLUB

March 19, 29 W. 39th St., 8.15 p.m. Secy., H. D. Vought, 95 Liberty St.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS

March 16, etc., weekly meetings, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NEW YORK TELEPHONE SOCIETY

March 16, 29 West 39th St., New York, 8 p.m. Secy., T. H. Laurence.

NORTHERN RAILWAY CLUB

March 27, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWEST RAILWAY CLUB

April 13, Minneapolis, Minn. Secy., T. W. Flannagan, Care Soo Line, Minneapolis.

NOVA SCOTIA SOCIETY OF ENGINEERS

March 11, April 8, monthly meetings, Halifax. Secy., S. Fenn.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

March 23, monthly meeting, Technical High School Hall, 8 p.m. June 22, annual meeting. Secy., T. M. Phetteplace.

PURDUE MECHANICAL ENGINEERING SOCIETY

March 17, etc., fortnightly meetings, Purdue University, Lafayette, Ind., 6:30 p.m. Secy., L. B. Miller.

RAILWAY CLUB OF KANSAS CITY

March 19.

RAILWAY CLUB OF PITTSBURGH

March 26, monthly meeting, Monongahela House, Pittsburgh, Pa., 8 p.m. Secy., J. D. Conway, Genl. Office, P.&.L.E.R.R.

RAILWAY SIGNAL ASSOCIATION

March 15, Chicago, Ill.

RENSSELAER SOCIETY OF ENGINEERS

March 12, etc., fortnightly meetings, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

ROAD AND TRACK SUPPLY ASSOCIATION

March 15–20, Exhibition, Coliseum, Chicago, Ill. Secy., John N. Reynolds, 160 Harrison St.

ROCHESTER ENGINEERING SOCIETY

March 12, April 9, monthly meetings. Secy., John F. Skinner, 54 City Hall.

ST. LOUIS RAILWAY CLUB

March 12, monthly meeting, Southern Hotel, 8 p.m. Paper: Piece Work in the Repair Shop, D. T. Taylor. Secy., B. W. Frauenthal.

SCRANTON ENGINEERS' CLUB

March 18, Board of Trade Bldg. Secy., A. B. Dunning.

TECHNICAL SOCIETY OF BROOKLYN

March 19, April 2, semi-monthly meetings, Arion Hall, Arion Pl., Brooklyn, N. Y., 8:30 p.m. Pres., M. C. Budell, 20 Nassau St., New York.

TECHNICAL SOCIETY OF THE PACIFIC COAST

April 2, San Francisco, Cal., Secy., Otto von Geldern, 1978 Bdwy.

TECHNOLOGY CLUB OF SYRACUSE

April 13, monthly meeting, 502 Bastable Blk., 8 p.m. Secy., Robert L. Allen.

WESTERN RAILWAY CLUB

March 16, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Jos. W. Tayler, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS

April 7, regular meeting. Paper: Reconstruction of the Street Car Tracks in Chicago, Geo. Weston. April 9, electrical section. Secy., J. H. Warder, 1737 Monadnock Blk., Chicago.

OFFICERS AND COUNCIL

PRESIDENT

Jesse M. Smith.......................................New York

VICE-PRESIDENTS

L. P. Breckenridge.......................................Urbana, Ill.
Fred J. Miller.......................................Center Bridge, Pa.
Arthur West.......................................E. Pittsburg, Pa.

Terms expire at Annual Meeting of 1909

Geo. M. Bond.......................................Hartford, Conn.
R. C. Carpenter.......................................Ithaca, N. Y.
F. M. Whyte.......................................New York

Terms expire at Annual Meeting of 1910

PAST PRESIDENTS

Members of the Council for 1909

Ambrose Swasey.......................................Cleveland, O.
John R. Freeman.......................................Providence, R. I.
Frederick W. Taylor.......................................Philadelphia, Pa.
F. R. Hutton.......................................New York
M. L. Holman.......................................St. Louis, Mo.

MANAGERS

G. M. Basford.......................................New York
A. J. Caldwell.......................................Newburg, N. Y.
A. L. Riker.......................................Bridgeport, Conn.

Terms expire at Annual Meeting of 1909

Wm. L. Abbott.......................................Chicago, Ill.
Alex. C. Humphreys.......................................New York
Henry G. Stott.......................................New Rochelle, N. Y.

Terms expire at Annual Meeting of 1910

H. L. Gantt.......................................Pawtucket, R. I.
I. E. Moultrop.......................................Boston, Mass.
W. J. Sando.......................................Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

TREASURER

William H. Wiley.......................................New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt.......................................New York

HONORARY SECRETARY

F. R. Hutton.......................................New York

SECRETARY

Calvin W. Rice.......................................29 W. 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
Alex. C. Humphreys
F. R. Hutton
Fred J. Miller
Frederic M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Edward F. Schnuck (2)
J. Waldo Smith (3)
Robert M. Dixon (4)
Waldo H. Marshall (5)

MEETINGS

Willis E. Hall (1), *Chairman*
Wm. H. Bryan (2)
L. R. Pomeroy (3)
Charles E. Lucke (4)
H. de B. Parsons (5)

PUBLICATION

Arthur L. Williston (1), *Chairman*
D. S. Jacobus (2)
H. F. J. Porter (3)
H. W. Spangler (4)
Geo. I. Rockwood (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Charles R. Richards (2)
Francis H. Stillman (3)
George J. Foran (4)
Hosea Webster (5)

LIBRARY

H. H. Suplee (1)
Ambrose Swasey (2)
Leonard Waldo (3)
John W. Lieb, Jr. (4), *Chairman*
Chas. L. Clarke (5)

HOUSE COMMITTEE

Henry S. Loud (1), *Chairman*
William Carter Dickerman (2)
Bernard Victor Swenson (3)
Francis Blossom (4)
Edward Van Winkle (5)

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Charles Wallace Hunt

On Affiliated Societies

F. R. Hutton, *Chairman*
R. H. Fernald
Alex. C. Humphreys
H. H. Suplee
F. W. Taylor

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
Charles Whiting Baker
L. D. Burlingame
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
R. C. Carpenter
Charles Wallace Hunt
J. W. Lieb, Jr.
Fred J. Miller

On Revision and Extension of the Code for Testing Gas Power Machinery

Charles E. Lucke, *Chairman*
E. T. Adams
Geo. H. Barrus
D. S. Jacobus
Arthur West

On Hudson-Fulton Celebration

Geo. W. Melville
M. L. Holman
Jesse M. Smith

SOCIETY REPRESENTATIVES
1909

On John Fritz Medal

Henry R. Towne (1) | F. R. Hutton (3)
Ambrose Swasey (2) | Charles Wallace Hunt (4)

On Board of Trustees United Engineering Societies Building

Chas. Wallace Hunt (1) | F. R. Hutton (2)
Fred J. Miller (3)

On Joint Library Committee

The Chairman of the Library Committee of The Am. Soc. M. E.

On National Fire Protection Association

John R. Freeman | Ira H. Woolson

On Joint Committee on Engineering Education

Alex. C. Humphreys | F. W. Taylor

On Government Advisory Board on Fuels and Structural Materials

Geo. H. Barrus | P. W. Gates
W. F. M. Goss

On Advisory Board National Conservation Commission

Geo. F. Swain | John R. Freeman
Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys | Fred J. Miller

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909

CHAIRMAN

F. R. Low

SECRETARY

Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman, *Chairman*
F. R. Hutton
G. I. Rockwood
H. H. Suplee
R. H. Fernald

GAS POWER MEMBERSHIP COMMITTEE

Robert T. Lozier, *Chairman*
Albert A. Cary
H. V. O. Coes
A. E. Johnson
F. S. King
D. B. Rushmore
A. F. Stillman
G. M. S. Tait
George W. Whyte
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
R. T. Kent
E. S. McClelland
C. W. Obert
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
H. R. Cobleigh
G. D. Conlee
R. S. deMitkiewicz
H. T. Eddy
L. V. Goebbels
L. N. Ludy
L. S. Marks
T. M. Phetteplace
G. J. Rathbun
W. Rautenstrauch
S. A. Reeve
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

J. R. Bibbins, *Chairman*
A. Bement
L. B. Lent

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
W. H. Blauvelt
E. P. Coleman
C. J. Davidson
H. J. K. Freyn
N. T. Harrington
G. L. Knight
J. L. Lyon
D. T. McLeod
V. E. McMullen
J. P. Sparrow
Paul Winsor

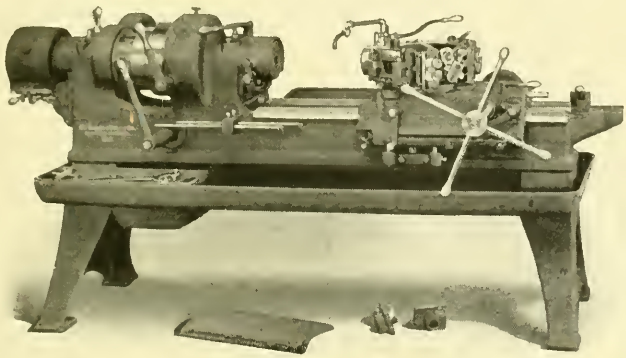
ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment

THE WARNER & SWASEY COMPANY

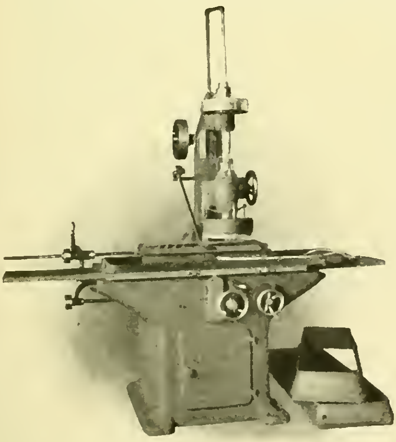
NEW YORK CLEVELAND CHICAGO



No 2 Hollow Hexagon Turret Lathe.

Rapid, accurate, economical, record producing Turret Lathes. The catalog describes them in detail. It will be sent on request.

WILL GRIND FROM 12 TO 20 TIMES FASTER THAN ANY OTHER SURFACE GRINDER



The P. & W. Vertical Surface Grinder

Cup shaped wheel covers full width of work, ensuring perfect flatness and rapid production.

Ten automatic vertical feeds from .0002 to .0020 through ratchet wheel.

Furnished with either revolving table for discs, rings, collars, etc., up to 16 inches, or with magnetic chuck.

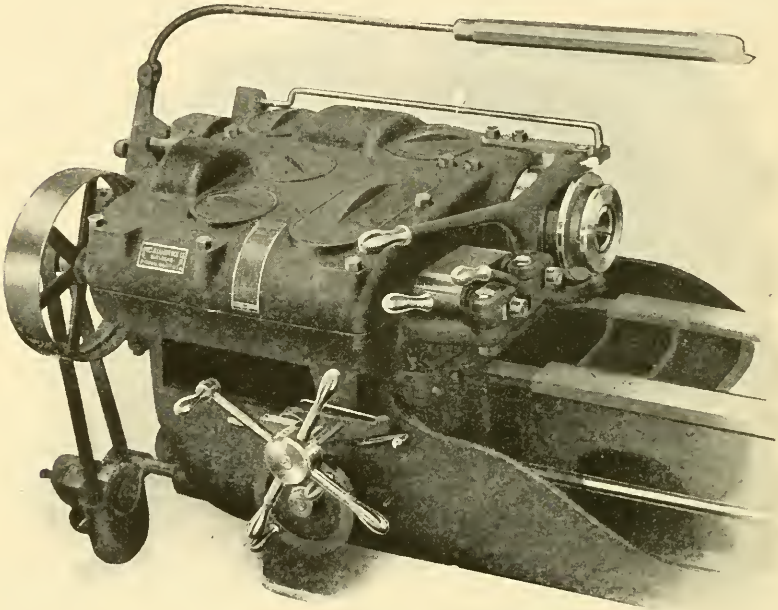
Belt or Motor Drive

PRATT & WHITNEY CO.

HARTFORD, CONN.

EXTRACTS FROM THE BOOK OF THE

Copies of the book



Cross Sliding Head

THE distinctive feature of the original Flat Turret Lathe was the flat, plate-shaped tool holder from which the lathe took its name. The original work-holding headstock possessed many distinctive features, such as the automatic chuck and roller feed, but it contained the now nearly obsolete cone pulley drive and back gear scheme. In the present machine we have combined an ideal scheme of speed regulation with many other desirable features.

The cross-feeding feature of the head grew out of our desire to get the best form of self-contained speed variator. After trying several combinations and positions, we found it best to arrange all the shafting and gearing in a horizontal plane, so that the lower half of

Springfield, Vt.
U. S. A.

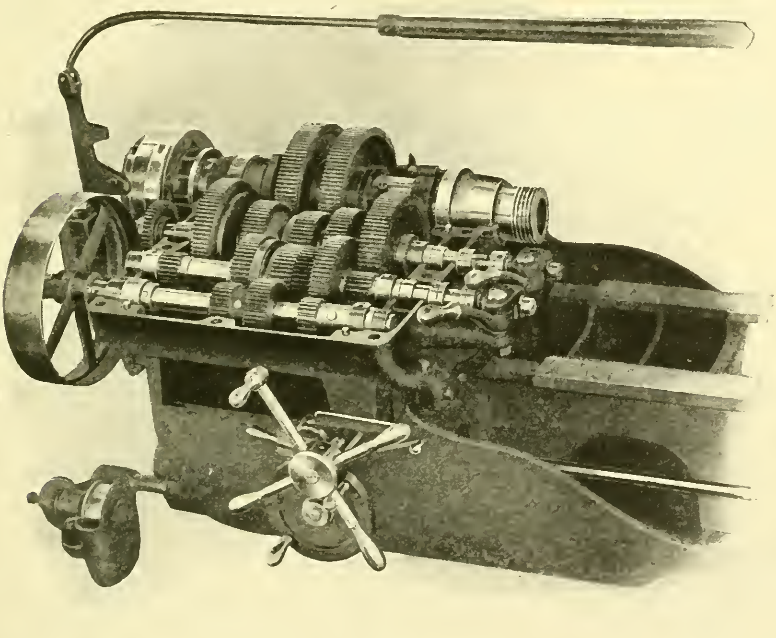
Jones & Lamson

Germany, Holland, Belgium, Switzerland, Austria-Hungary,
M. Koyemann, Charlottenstrasse 112 Dusseldorf, Germany.

these running parts could be *submerged in oil* to insure perfect lubrication.

This determined the adoption of a shallow pan-shaped frame for the headstock, into which were placed all the clutches and bearings, including main spindle bearings. The natural form of bed for holding this headstock made the way open to give the headstock a cross travel, which we had long realized was a most desirable feature, as shown by our earlier patents.

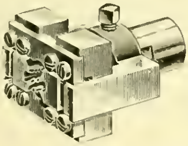
A most fortunate combination was the result. We not only obtained a most compact and symmetrical machine, but in one machine we succeeded in getting practically all of the features made desirable by present-day conditions.



ERRINGTON OPENING DIE

41 Cortlandt St., New York

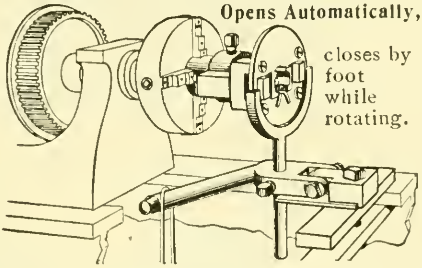
Cuts Parallel Thread to Shoulder



Can be used on DRILL PRESS, SPEED LATHE, ENGINE LATHE, TURRET LATHE.

Skeleton Frame Sheds Chips

	STD.		PIPE
No. 1 Threads to..........	5/8"	—	3/8"
No. 2 Threads to..........	1"	—	3/4"
No. 3 Threads to..........	1½"	—	1"
No. 4 Threads to..........	2"	—	1½"



Opens Automatically, closes by foot while rotating.

WE BUILD A COMPLETE LINE OF NEW AND UP-TO-DATE

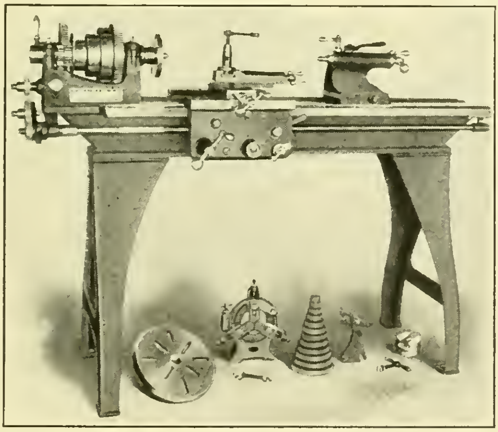
BOLT AND NUT
MACHINERY

Including ...

Bolt Cutters (threaders), Bolt and Rivet Headers, Upsetting and Forging Machines, Hot Pressed Nut Machines, Nut Tappers, Washer Machines, Wire Nail Machines and Lag Screw Gimlet Pointers

THE NATIONAL MACHINERY CO
TIFFIN, OHIO, U.S.A.

"Star" Lathes



9" and 11" swing for foot and power with draw-in chuck, taper and milling attachments for experimental and laboratory work, light manufacturing and tool making.

Send For Catalog B

The SENECA FALLS MFG. CO.

268 WATER STREET, SENECA FALLS, N. Y., U. S. A

(P-1)

ADVERTISING SUPPLEMENT

SECTION 2

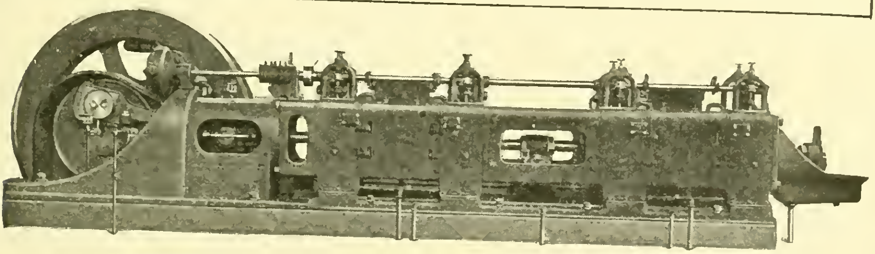
Power Plant Equipment

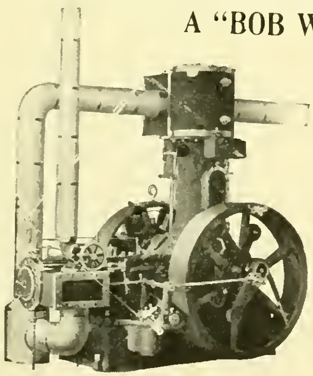
CATALOGUE ANNOUNCEMENT

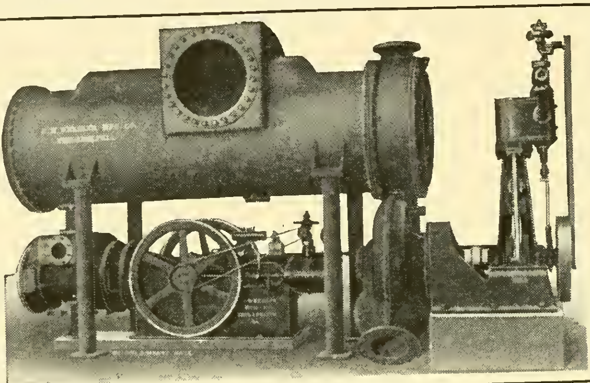
Nelson Valve Company

PHILADELPHIA

This 1909 Catalogue is now ready for distribution: write for it immediately to secure your copy from the first edition.







YEAR BOOKS

The Society wishes to have a file of year books or catalogues complete since its formation. Will members who have any of the following numbers either send them to the Society or correspond with the Secretary

No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

The American Society of Mechanical Engineers
29 West 39th Street, New York

ADVERTISING SUPPLEMENT

SECTION 3

Hoisting and Conveying Machinery

Power Transmission

ADVERTISING SUPPLEMENT

SECTION 4

Engineering Miscellany

ENGINEERING SCHOOLS AND COLLEGES

CLARKSON SCHOOL OF TECHNOLOGY

Thomas S. Clarkson Memorial

ORGANIZED UNDER CHARTER OF THE UNIVERSITY OF THE STATE OF NEW YORK. Courses leading to degrees of Bachelor of Science in Chemical, Civil, Electrical and Mechanical Engineering, comprising four years of thorough training and resident college work in theory and practice of engineering. Copies of Clarkson Bulletin, published quarterly, mailed on application. WM. S. ALDRICH, *Director*.

POTSDAM, N. Y.

POLYTECHNIC INSTITUTE OF BROOKLYN

COURSE IN MECHANICAL ENGINEERING. Evening Post-Graduate Courses. Fred. W. Atkinson, Ph.D., President; W. D. Ennis, Member A. S. M. E., Professor Mechanical Engineering.

TUFTS COLLEGE

DEPARTMENT OF ENGINEERING. Civil, Mechanical, Electrical and Chemical Engineering. New laboratories and excellent equipment. Beautiful site within four miles of Boston. Preparatory department for students who have had engineering practice, but insufficient preparation for college work. For information concerning courses and positions of graduates, address,

PROF. G. C. ANTHONY, *Dean*.

TUFTS COLLEGE P. O., MASS.

THE RENSSELAER POLYTECHNIC INSTITUTE

Courses in Civil, Mechanical and Electrical Engineering and General Science leading to the degrees, C.E., M.E., E.E. and B.S.

Unsurpassed laboratories for Mechanical and Electrical Engineering.

Catalogue sent upon application, Troy, N. Y.

THE UNIVERSITY OF MICHIGAN

Ann Arbor, Mich.

DEPARTMENT OF ENGINEERING. Courses offered in Civil, Mechanical, Electrical, Chemical, Marine Engineering and Naval Architecture, Architecture and Architectural Engineering, and Geological Engineering. Four, five and six year courses. University attendance 5000; Engineering attendance 1350.

For special Bulletins address,

JAMES P. BIRD, *Secretary*.

NEW YORK UNIVERSITY SCHOOL OF APPLIED SCIENCE

DEPARTMENTS OF Civil, Mechanical and Chemcal Engineering.

For announcements or information, address

CHARLES HENRY SNOW, *Dean*

UNIVERSITY HEIGHTS, N. Y. CITY.

PROFESSIONAL CARDS

THE ARNOLD COMPANY

Engineers—Constructors

Electrical—Civil—Mechanical

181 LaSalle Street, CHICAGO

EARLE C. BACON

Member A. S. M. E.

Hoisting, Crushing and Mining Machinery

Havemeyer Building, NEW YORK.

BERT. L. BALDWIN

Member A. S. M. E. and A. I. E. E.

Plans, Specifications and Superintendence of Manufacturing Buildings, Plants and Equipments of same.

Perin Building, CINCINNATI, OHIO.

D. HURLEY & COMPANY

Factory and Mill Engineering.

17 Custom House Street, PROVIDENCE, R. I.

CHAS. T. MAIN

Member A. S. M. E.

Mill Engineer and Architect.

Room 911, 45 Milk Street, BOSTON, MASS.

J. G. O'NEIL

Member A. S. M. E.

Contracting Engineer; Boilers, Engine Pumps and Steam Specialties.

304 The Rookery, CHICAGO, ILL.

CLASSIFIED LIST OF ADVERTISERS

AIR CONDITIONING.
Carrier Air Conditioning Co., New York.

AIR WASHING.
Carrier Air Conditioning Co., New York.

ARBORS.
Morse Twist Drill & Machine Co., New Bedford, Mass.

AUTOMATIC MACHINERY.
Diamond Chain & Mfg. Co., Indianapolis, Ind.

AUTOMATIC STOKERS.
Detroit Stoker & Foundry Co., Detroit, Mich.

BARRELS, TUMBLING.
Whiting Foundry Equipment Co., Harvey, Ill.

BELTING CHAIN.
Link Belt Co., Philadelphia, Pa.

BELTING, LEATHER.
Schieren Co., Chas. A., New York.

BLOWERS, POSITIVE PRESSURE.
American Gas Furnace Co., New York.

BLOW PIPES AND BLOWERS.
American Gas Furnace Co., New York.

BLUE PRINTING MACHINES.
Buckeye Engine Co., Salem, O.

BOILERS.
Heine Safety Boiler Co., St. Louis, Mo.
Murray Iron Works Co., Burlington, Iowa.
Robb-Mumford Boiler Co., S. Framingham, Mass.

BORING MILLS.
Manning, Maxwell & Moore, New York.

BOLTS AND NUTS.
Russell, Burdsall and Ward Bolt and Nut Co., Port Chester, N. Y.

BOLT AND NUT MACHINERY.
Manning, Maxwell & Moore, New York.
National Machinery Co., Tiffin, O.

CAR DUMPERS.
Dodge Co., J. M., Philadelphia, Pa.

CAR HAULS, WIRE CABLE.
Jeffrey Mfg. Co., Columbus, O.

CARS, SCALE.
Alliance Machine Co., Alliance, O.

CASE HARDENING MACHINES.
American Gas Furnace Co., New York.

CASTINGS, SPECIAL HEAVY.
Hooven, Owens & Rentschler Co., Hamilton, O.

CENTERING MACHINES.
Whiton Machine Co., D. E., New London, Conn.

CHAINS, DODGE, EWART, LEY, MONOBAR, RENOLD, Etc.
Link Belt Co., Philadelphia, Pa.

CHAIN DRIVES.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHAINS, SPROCKET.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHUCKS, DRILL.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Whiton Machine Co., D. E., New London, Conn.

CHUCKS, LATHE.
Whiton Machine Co., D. E., New London, Conn.

CLUTCHES, FRICTION.
Dodge Mfg. Co., Mishawaka, Ind.

COAL AND ASHES HANDLING MACHINERY.
Link Belt Co., Philadelphia, Pa.

COAL CUTTERS.
Jeffrey Mfg. Co., Columbus, O.

COAL STORAGE.
Dodge Co., J. M., Philadelphia, Pa.

COMPRESSORS, AIR.
Riverside Engine Co., Oil City, Pa.

COMPRESSORS, GAS.
Riverside Engine Co., Oil City, Pa.

CONDENSERS, SURFACE, JET AND BAROMETRIC.
Wheeler Mfg. Co., C. H., Philadelphia, Pa.

CONVEYING MACHINERY.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

COOLING.
Carrier Air Conditioning Co., New York.

COPPER CONVERTING MACHINERY.
Alliance Machine Co., Alliance, O.

COUNTERBORES.
Morse Twist Drill & Machine Co., New Bedford, Mass.

COUNTERSHAFTS.
Builders Iron Foundry, Providence, R. I.
Dodge Mfg. Co., Mishawaka, Ind.

COUPLING, SHAFT.
Dodge Mfg. Co., Mishawaka, Ind.

CRANES.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Dodge Co., J. M., Philadelphia, Pa.
Link Belt Co., Philadelphia, Pa.
Manning, Maxwell & Moore, New York.
Whiting Foundry Equipment Co., Harvey, Ill.

CUPOLAS, FOUNDRY.

Whiting Foundry Equipment Co., Harvey, Ill.

CUTTERS, MILLING.

Morse Twist Drill & Machine Co., New Bedford, Mass.

DEHUMIDIFYING.

Carrier Air Conditioning Co., New York.

DIES, AUTO—OPENING

Errington, F. A., New York.

DRILLS.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.

DRILLS, PORTABLE.

General Electric Co., Schenectady, N. Y.

DRAFTSMAN'S SQUARE.

Kelsey, D. J., New Haven, Conn.

DYNAMOS.

General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELECTRICAL MACHINERY.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

ELEVATORS.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

ELEVATING AND CONVEYING MACHINERY.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.

ENGINEERS.

Arnold Co., The, Chicago, Ill.
Bacon, Earle C., New York City.
Baldwin, Bert L., Cincinnati, O.
Dodge, J. M. Co., Philadelphia, Pa.
Hurley, D. & Co., Providence, R. I.
Link Belt Co., Philadelphia, Pa.
Main, Charles T., Boston, Mass.
O'Neil, J. G., Chicago, Ill.

ENGINEERING COLLEGES.

Clarkson School of Technology, Potsdam, N.Y.
New York University, New York City.
Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Rensselaer Polytechnic Institute, Troy, N. Y.
Tufts College, Tufts College, Mass.
University of Michigan, Ann Arbor, Mich.

ENGINES, GAS.

Buckeye Engine Co., Salem, O.
DuBois Iron Works, DuBois, Pa.
National Meter Co., New York.
Riverside Engine Co., Oil City, Pa.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

ENGINES, STEAM.

American Engine Co., Bound Brook, N. J.
Buckeye Engine Co., Salem, O.
Hooven, Owens & Rentschler Co., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Ridgway Dynamo & Engine Co., Ridgway, Pa.
St. Louis Iron & Machine Works, St. Louis, Mo.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

FILES.

American Swiss File and Tool Co., New York.
Reichhelm & Co., E. P., New York.

FORGES, GAS.

American Gas Furnace Co., New York.

FOUNDRY EQUIPMENT.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, ANNEALING AND TEMPERING.

American Gas Furnace Co., New York.

FURNACES.

Whiting Foundry Equipment Co., Harvey Ill.

FURNACES, GAS.

American Gas Furnace Co., New York.

GAS GENERATORS.

American Gas Furnace Co., New York.

GASKETS.

American Goetze-Gasket & Packing Co., New York.

GASKETS, COPPER.

American Goetze-Gasket & Packing Co., New York.

GAS PRODUCERS.

Struthers-Wells Co., Warren, Pa.

GAGES, WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Manning, Maxwell & Moore, New York.

GEAR CUTTING MACHINES.

Manning, Maxwell & Moore, New York.
Newark Gear Cutting Machine Co., Newark, N. J.
Whiton Machine Co., D. E., New London, Conn.

GEARS.

Dodge Mfg. Co., Mishawaka, Ind.
Newark Gear Cutting Machine Co., Newark, N. J.

GENERATING SETS.

American Engine Co., Bound Brook, N. J.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

GOVERNORS, PUMP.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.

GRAPHITE.

Dixon Crucible Co., Jos., Jersey City, N. J.

GRINDERS, TOOL.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Pratt and Whitney Co., Hartford, Conn.

GRINDING AND POLISHING MACHINERY.

Builders Iron Foundry, Providence, R. I.

HAMMERS, STEAM.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

HANGERS, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

HEATERS, FEEDWATER.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

HEATING MACHINES.

American Gas Furnace Co., New York.

HOISTING AND CONVEYING MACHINERY.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTS.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTS, MAGNETIC.

Electric Controller and Mfg. Co., Cleveland, O.

HUMIDIFYING.

Carrier Air Conditioning Co., New York.

HUMIDITY CONTROL, AUTOMATIC

Carrier Air Conditioning Co., New York.

HYDRAULIC MACHINERY.

Alliance Machine Co., Alliance, O.

INJECTORS.

Detroit Lubricator Co., Detroit, Mich.
Manning, Maxwell & Moore, New York.
Ohio Injector Co., Wadsworth, O.

LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.
Warner & Swasey Co., Cleveland, O.

LATHES, BENCH.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, CHUCKING.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, TURRET.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, FOOT POWER.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, ENGINE.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, WOOD.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LOCOMOTIVE—COALING STATIONS

Dodge Co., J. M., Philadelphia, Pa.

LOCOMOTIVES, ELECTRIC.

Jeffrey Mfg. Co., Columbus, O.

LUBRICANTS.

Dixon Crucible Co., Jos., Jersey City, N. J.

LUBRICATORS.

Detroit Lubricator Co., Detroit, Mich.
Ohio Injector Co., Wadsworth, O.

MACHINERY DEALERS.

Manning, Maxwell & Moore, New York.

MAGNETS, LIFTING.

Electric Controller and Mfg. Co., Cleveland, O.

MANDRELS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

METAL, ANTI-FRICTION.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METALS, BEARING.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METERS, VENTURI.

Builders Iron Foundry, Providence, R. I.

METERS, WATER.

National Meter Co., New York.

MILLING MACHINES.

Manning, Maxwell & Moore, New York.

MOTORS, ELECTRIC.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

OILING DEVICES.

Detroit Lubricator Co., Detroit, Mich.

PIPE CUTTING AND THREADING MACHINES.

Manning, Maxwell & Moore, New York.

PRESSES, HYDRAULIC.

Alliance Machine Co., Alliance, O.

PISTONS, METAL FOR FACING.

Allan & Son, A., New York.

PAPER MILL MACHINERY.

Sandusky Foundry & Machine Co., Sandusky, O.

PLANERS, METAL.

Manning, Maxwell & Moore, New York.

PULLEYS.

Dodge Mfg. Co., Mishawaka, Ind.
National Brake and Clutch Co., Boston, Mass.

PUMPS, CENTRIFUGAL.

Jeanesville Iron Works Co., Hazleton, Pa.
Morris Machine Works, Baldwinsville, N .Y.
Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, GAS DRIVEN.

Riverside Engine Co., Oil City, Pa.

PUMPS, VACUUM.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, PRESSURE.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, TURBINE.

Kerr Turbine Co., Wellsville, N. J.

PUNCHES AND SHEARS.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

REAMERS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

REGULATORS, PUMP.

Davis Co., John, Chicago, Ill.

REGULATORS, FEED WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

RIVET HEADERS.

National Machinery Co., Tiffin, O.

RIVETERS, HYDRAULIC.

Alliance Machine Co., Alliance, O.

ROLLING MILL MACHINERY.

Alliance Machine Co., Alliance, O.

SCREW PLATES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

SEPARATORS, STEAM AND OIL.

Albany Steam Trap Co., Albany, N. Y.
Lindstrom, John T., Allentown, Pa.

SHAPERS.

Manning, Maxwell & Moore, New York.

SMOKELESS FURNACE.

Detroit Stoker & Foundry Co., Detroit, Mich.

SOCKETS AND SLEEVES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

SPROCKETS.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

STEEL PLATE CONSTRUCTION.

Robb-Mumford Boiler Co., South Framingham, Mass.
Struthers-Wells Co., Warren, Pa.

STOKERS, MECHANICAL.

Detroit Stoker & Foundry Co., Detroit, Mich.

SUPERHEATERS.

Heine Safety Boiler Co., St. Louis, Mo.

TAPPING MACHINES AND ATTACHMENTS.

F. A. Errington, New York.

TAPS AND DIES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

TELPHERS.

Dodge Co., J. M., Philadelphia, Pa.

TOWERS, HOISTING.

Dodge Co., J. M., Philadelphia, Pa.

TRACK, INDUSTRIAL.

Whiting Foundry Equipment Co., Harvey, Ill.

TRAMWAYS, BRIDGE.

Dodge Co. J. M., Philadelphia, Pa.

TRAPS, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Lindstrom, John T., Allentown, Pa.

TRANSMISSION MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Link Belt Co., Philadelphia, Pa.

TURBINES, STEAM.

General Electric Co., Schenectady, N. Y.
Hoover, Owens & Rentschler Co., Hamilton, O.
Kerr Turbine Co., Wellsville, N. Y.

TURRET LATHES.

Jones & Lamson Machine Co., Springfield, Vt
Warner & Swasey Co., Cleveland, O.

UPSETTING AND FORGING MACHINES.

National Machinery Co., Tiffin, O.

VALVE DISCS, METALLIC.

Allan & Son, A., New York.

VALVES, AUTOMATIC.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BACK PRESSURE.

Davis Co., John, Chicago, Ill.
Kennedy Valve Co., Elmira, N. Y.
Walch & Wyeth, Chicago, Ill.

VALVES, BOILER STOP.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BLOW-OFF.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.

VALVES, CHECK.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, FLOAT.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, GATE.

Albany Steam Trap Co., Albany, N. Y.
Kennedy Valve Co., Elmira, N. Y.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, GLOBE.

Albany Steam Trap Co., Albany, N. Y.
Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, HYDRAULIC.

Nelson Valve Co., Philadelphia, Pa.

VALVES, NON-RETURN.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, RADIATOR.

Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.

VALVES, REDUCING.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

VALVES, REGULATING.

Davis Co., John, Chicago, Ill.

VALVES, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Davis Co., John, Chicago, Ill.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, SWING GATE.

Walch & Wyeth, Chicago, Ill.

WATER COOLING TOWERS.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

WATER TOWERS.

Struthers-Wells Co., Warren, Pa.

WATER COLUMNS.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Davis Co., John, Chicago, Ill.

WATER SOFTENERS AND PURIFIERS.

Dodge Mfg. Co., Mishawaka, Ind.

WHEELS, SHEAVE, SPROCKET, TRACTION.

Link Belt Co., Philadelphia, Pa.

WIRE NAIL MACHINES.

National Machinery Co., Tiffin, O.

WIRE ROPE.

Roebling's Sons Co., John A.

WOOD POLISHING WHEELS.

Builders Iron Foundry, Providence, R. I.

WOODWORKING MACHINERY.

Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.

WRENCHES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

ALPHABETICAL LIST OF ADVERTISERS

THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

APRIL 1909

NEXT MONTHLY MEETING, APRIL 13
SPRING MEETING, WASHINGTON, D. C., MAY 4-7

G Canes

HONORARY MEMBER
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

APRIL 1909 VOL. 31 No. 4

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED AT 2427 YORK ROAD - - - - BALTIMORE, MD.
EDITORIAL ROOMS, 29 W. 39TH STREET - - - - NEW YORK

CONTENTS

THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.
Price, one dollar per copy—fifty cents per copy to members. Yearly subscription, $7.50; to members, $5.
Application filed for entry at the Postoffice, Baltimore, Md., as second-class mail matter under the act of March 3, 1879

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 APRIL 1909 NUMBER 4

THE JOHN FRITZ MEDAL AWARD

TUESDAY EVENING, APRIL 13

Tuesday evening, April 13, will be the occasion for publicly conferring the John Fritz Medal upon Mr. Chas. T. Porter, Honorary Member of the Society.

The ceremony will be held under the auspices of the John Fritz Board which is made up of representatives from the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, thus representing the entire engineering profession. It will take place in the large auditorium of the Engineering Societies Building, No. 29 West 39th Street, New York. It is the wish of the Board to give distinction to the event, and to make these awards year by year memorable and fittingly conspicuous. Besides the simple ritual of the presentation of the medal, in the presence of invited guests and distinguished representatives of engineering, there will be addresses by representatives of the four groups of the profession most concerned.

The medal was established in 1902 to perpetuate the memory of the achievements of John Fritz, Honorary Member and Past President, Am. Soc. M. E. It is awarded for notable scientific or industrial achievement.

Previous awards have been, to Lord Kelvin for his work in the development of the telegraph, and other scientific achievements; to

George Westinghouse, Hon. Mem. Am. Soc. M. E., for the invention and development of the air brake; to Alexander Graham Bell for his invention and development of the telephone. It will be awarded to Charles T. Porter for his part in the origination of the high speed steam engine.

Members, ladies and the public are invited.

PROGRAM

Tuesday Evening, April 13, *at eight-thirty*

In the Engineering Societies Building,
29 West 39th St., New York

Ceremony Conferring

THE JOHN FRITZ MEDAL

upon

CHARLES T. PORTER, HONORARY MEMBER, AM.SOC.M.E.

For his part in the origination of the high speed steam engine

Henry R. Towne, Past Pres. Am. Soc. M. E., Presiding Officer

THE DEBT OF MODERN INDUSTRIAL CIVILIZATION TO THE STEAM ENGINE

Address by Dean W. F. M. Goss, Mem. Am. Soc. M. E.

Presentation of Medal

THE DEBT OF THE MODERN STEAM ENGINE TO CHARLES T. PORTER

Address by Dr. F. R. Hutton, Honorary Secretary, Am. Soc. M. E.

DEBT OF THE ERA OF STEEL TO THE HIGH-SPEED STEAM ENGINE

Address by Robert W. Hunt, Mem. Am. Soc. C. E., Past President Am. Inst. M. E. and Am. Soc. M. E.

THE DEBT OF THE ERA OF ELECTRICITY TO THE HIGH-SPEED STEAM ENGINE

Address by Frank J. Sprague, Past-President, Am. Inst. E. E., Mem. Am. Soc. C. E.

Distinguished invited guests will occupy seats upon the platform.

THE WASHINGTON MEETING

LOCAL COMMITTEE

Walter A. McFarland, *Chairman*

Gustav Ayres
Albert H. Buckler
Charles Eli Burgoon
Gordon Campbell
Howard A. Coombs
James B. Dillard
William A. E. Doying
Charles E. Foster
H. A. Gillis
James Hamilton
Frederick E. Healy
Herman Hollerith
J. A. Holmes
Arthur E. Johnson
Frank B. King
Hervey S. Knight
Walter R. Metz
George L. Morton
Harold P. Norton
Willard L. Polland
John E. Powell
Alfred H. Raynal
William B. Ridgely
W. E. Schoenborn
George R. Simpson
Charles F. Sponsler
Lucien N. Sullivan
William B. Upton
Charles V. C. Wheeler
Earl Wheeler

Committee of Washington Society of Engineers

W. A. McFarland, Mem. Am. Soc. M. E., *Chairman.*
A. E. Johnson, Mem. Am. Soc. M. E.
A. H. Raynal, Mem. Am. Soc. M. E.
W. E. Schoenborn, Mem. Am. Soc. M. E.
W. B. Upton, Mem. Am. Soc. M. E.
H. W. Fuller, Mem. Am. Inst. E. E.
John C. Hoyt, Mem. Am. Soc. C. E., Secretary, Washington Soc. Engrs.
D. S. Carll, Mem. Am. Soc. C. E., President, Washington Soc. Engrs.

The Society is indebted to the Meetings Committee, to the Local Committee of Washington and to the Washington Society of Engineers for the following delightful program. The Society also wishes to acknowledge the honor shown in appointing as a Reception Committee men representing each of the National Engineering Societies.

Tuesday, May 4

8.15 p.m.

Informal reception at the New Willard Hotel.

Address of welcome by Hon. Henry B. F. Macfarland, President of the Board of District Commissioners.

Response by Mr. Jesse M. Smith, President of the Society.

Wednesday, May 5

Professional session at 9.15 a.m

Sight-seeing automobile trips about the city at 10 a. m. for the ladies.

Reception of members and their guests by the President of the United States in the East Room of the White House at 2.30 p.m.

Trips to near-by points of interest at 4 p.m.

Illustrated lecture by Mr. F. H. Newell, Director of the Reclamation Service on "Home-Making in the Arid Regions," at 8.15 p.m.

Thursday, May 6

Short professional session at 9.15 a.m.

Trips for the Ladies to points of interest in and about the city at 9.15 a.m.

Special exhibition drill by troops at Fort Myer at 2.00 p.m.

Social reunion. Address by Rear-Admiral Melville on "The Engineer in the Navy," at 8.15, to be followed by presentation to the National Gallery of a portrait of Rear-Admiral Melville, with acceptance by Dr. C. D. Wolcott, representing the nation.

Friday, May 7

Professional session at 9.15 a.m.

CONVENTION NOTES

The reception of the members and guests by President Taft will be one of the pleasant functions of the convention.

The address by F. H. Newell, Director of the U. S. Reclamation Service, will be of extraordinary interest. Mr. Newell is in a position to command a large view of this important branch of the government's work of reclamation and the lecture will be illustrated by colored lantern slides showing marvelous transformations of arid regions into beautiful and fertile home-sustaining lands

It is possible that during the convention there may be an ascension of a dirigible balloon and an aëroplane. If so, the Secretary of War, Mr. J. M. Dickinson, proposes, provided the conditions are favorable, to invite the members and guests. Those who attended the addresses on aëronautics at the time of the annual meeting given through the courtesy of Brig-Gen. Allen, Major Geo. O. Squier and Lieut. Frank P. Lahm, and saw the wonderful moving pictures of dirigible balloons and aëroplanes in flight will realize in a measure the oppo -tunity for witnessing an actual ascension.

A very interesting feature will be two exhibition drills which will be given by the United States troops stationed at Fort Myer. These will be held in the open field or in the riding hall, according to the condition of the weather, so that in any event the convention guests may depend upon seeing the drill in comfort.

On Thursday evening, the address by Past-President Geo. W. Melville, Rear-Admiral, Retired, and former Engineer-in-Chief of the Navy, on "The Engineer in the Navy," will undoubtedly prove highly interesting, as Rear-Admiral Melville is a noted speaker. Upon this evening there will be a presentation to the National Gallery of a portrait of Rear-Adm. Melville, painted by Sigismond de Ivanowsky. It will be received for the National Gallery by Dr. Chas. D. Wolcott, Secretary of the Smithsonian Institution. The portrait is presented by friends and admirers of Rear-Admiral Melville.

It is unnecessary to emphasize the pleasure and instruction of visiting the places of interest in Washington. The fact that Congress will be in session at that time is an added attraction.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

Special concessions have been secured for members and guests attending the Spring Meeting in Washington, May 4–7, 1909.

The special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between April 30 and May 6 inclusive. At the same time request a certificate, *not a receipt*. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Find out from your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after May 7.

d An agent of the Trunk Line Association will validate certificates May 5, 6 and 7. No refund of fare will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate, and to turn it in at Headquarters. Even though you may not use it this will help others to secure the reduced rate.

f If certificate is validated, a return ticket to destination can be purchased, up to May 11, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

The Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

The Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The New England Passenger Association, except via Bangor and Aroostook R. R., Rutland R. R., N. Y. O. & W. R. R., Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

The Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

TRAIN SCHEDULES

The following trains are suggested, via Pennsylvania Railroad.

Lv. New York, Tuesday, May 4	10.55 a.m.
Lv. North Philadelphia	1.00 p.m.
Lv. Baltimore	3.12 p.m.
Ar. Washington	4.15 p.m.
Lv. New York, Wednesday, May 5	12.10 a.m.
Lv. Baltimore	6.01 a.m.
Ar. Washington, Wednesday, May 5	7.12 a.m.
Lv. St. Louis, Monday, May 3	12.45 p.m.
Lv. Chicago	3.15 p.m.
Lv. Indianapolis	7.20 p.m.
Lv. Detroit	8.05 p.m.
Lv. Cincinnati	9.00 p.m.
Lv. Cleveland	11.30 p.m.
Lv. Columbus, Tuesday, May 4	12.45 a.m.
Lv. Pittsburg	7.30 a.m.
Lv. Baltimore	5.15 p.m.
Ar. Washington	6.22 p.m.

HOTEL ACCOMMODATIONS

Members should bear in mind that Congress will be in session at the time of the convention, and also that this is the most delightful season of the year in Washington. As a result the city has many visitors and a consequent large demand on its hotel accommodations. Members expecting to attend the convention should engage rooms immediately.

The letter from the hotel assigning rooms should be preserved, and presented at the time the rooms are demanded. Two days before arriving in Washington, the hotel should be notified of the exact time of expected arrival, referring to the letter engaging rooms. If one hotel cannot provide satisfactory accommodations, immediate correspondence with others will doubtless secure what is desired.

Hotel Rates for Spring Meeting at Washington
Minimum Rates

	American Plan				European Plan			
	without bath		with bath		without bath		with bath	
	Single Room	Double Room	Single Room	Double Room	Single Room	Double Room	Single Room	Double Room
New Willard					2.50	4.00	3.50	5.00
Shoreham	5.00	9.00	5.50	10.00	2.50	4.00	3.00	5.00
Arlington	5.00	10.00	7.00	12.00	2.00	4.00	4.00	6.00
Raleigh					2.00	3.00	3.00	4.00
Ebbitt	2.50	5.00	4.50	7.00				
St. James					1.50	2.00	2.50	3.50
Cochran	4.00	7.00	4.50	9.00				
Riggs	3.00	6.00	4.00	8.00				
Normandy	3.50	6.00	4.00	9.00	1.50	3.00	3.00	4.00

If baggage is to be sent by express, checks can be given the baggage expressman immediately upon arrival. Trolleys leave the station for all hotels. Automobile passengers are allowed only a very small steamer trunk; carriage passengers, one medium-sized trunk. Extra baggage can be managed by taking as many carriages as there are trunks, or by sending some pieces by baggage express. The traveler wishing an automobile or carriage should give his checks to the uniformed porter immediately upon arrival as no carriages will be assigned to travelers until their baggage has first been brought to the platform in front of the station.

THE MARCH MEETING

A particularly interesting occasion was the lecture on "Modern Physics," given by Dr. William Hallock, Professor of Physics, Columbia University, at the regular monthly meeting, Tuesday evening, March 9.

The lecture included a review of discoveries introductory to the X-ray, radio-activity and allied phenomena; experimental demonstration of different forms of radiation, including heat; development of the essential identity of radiant light, heat and Hertz waves, together with the evidence of the electro-magnetic nature of light radiations; differentiations between these forms of radiation and those of so-called radio-active material, followed by the bearing of the facts developed by radio-activity upon the possible genesis of the chemical elements; the kinetic theory of gases and its relation to the modern theory of solutions; the moving ion as the determining factor in electrical conduction; the distinction between the chemical and the physical ion; the atom and the relation of its structure to the phenomena of radiation and absorption; the principle of relativity and its relation to the structure of the atom and the electron; the universal application of the *force*, *mass*, *time* theory to molecular and cosmic phenomena.

JOINT MEETING ON CONSERVATION

The meeting of the national engineering societies on the conservation of our natural resources was held in the Engineering Societies' Building on the evening of March 24. Mr. Onward Bates, president of The Am. Soc. C. E., who was to have presided, was unable to attend, and Dr. James Douglas, past-president of The Am. Inst. M. E., acted as chairman. At the opening of the meeting, he announced a telegram from President Taft, which was read by Mr. John Hays Hammond, as follows:

THE WHITE HOUSE

WASHINGTON, March, 24.

JOHN HAYS HAMMOND,

Please say to Joint Engineering Societies that I am greatly gratified to know of their coöperation in the movement for the conservation of the natural resources of the country. The members of these societies, with their technical knowledge, are not only better advised as to the necessity for such conservation, but are more competent to suggest the methods by which such conservation can be carried out. I have already pledged the administration to as full support as possible of the policy, and I am glad to renew my expression of sympathy with the movement, and to state my high estimate of the value of the aid which can be rendered by the United Engineering Societies.

WM. H. TAFT.

In his opening remarks Dr. Douglas said that in a great movement of this kind there could be no dividing line between engineers in different branches of the profession. The great inventions like that of the Bessemer process had required a combination of the skill of engineers who had specialized in different fields. He said that in looking back we must be struck with the advance that had been made in the reduction of waste in the use of natural supplies, especially in saving coal, both in mining it and in using it in metallurgical work.

The first address was upon The Conservation of Water, by John R. Freeman, consulting engineer of the Department of Additional Water Supply for the City of New York. He spoke of the relation of stream flow to lumbering, emphasizing the importance of accurate stream measurements in order to obtain precise knowledge of the effect of forests and of the value of water powers. Interesting

figures were given, comparing the efficiency of turbines of the old days with those of the present time. Other phases of the conservation of water, such as the purity of the water courses, navigation, irrigation, etc., were considered. He recommended that the different states should collect facts regarding the notable opportunities for power development within their borders, making careful surveys, thus placing reliable information at the disposal of those inclined to take advantage of such natural opportunities for power.

The address of Dr. R. W. Raymond, Secretary of The American Institute of Mining Engineers, was upon Conservation by Legislation. He defined true conservation as the diminution, not of use but of waste. The best method for the prevention of waste lies in the progressive education of the people, rather than by legislation. He urged that government information pertaining to natural resources and their conservation should be collected with care and not hurried; and stated without bias or argument in favor of any measure or policy. Hasty and ill-considered legislation, especially if reduced by selfish interests, is a peril. He dealt with specific examples of such legislation and urged that the work of the departments of the Federal government should be carefully planned in advance instead of expanding without a definitely arranged plan.

Mr. Charles Whiting Baker, Editor of Engineering News, spoke on The Waste of our Natural Resources by Fire. He gave new statistics upon the fire laws in the United States, with the striking illustration that we are burning up every year in this country a street of buildings a thousand miles long that would reach from New York to Chicago. That this destruction is not necessary is proved by the experience of European countries where the per capita fire loss is in most cases only a few cents annually, while in this country it is $2.50. Referring to the destruction by forest fires, he said that effective laws for the protection of forests must be enacted before capital will be invested in the development or preservation of timber lands.

The last address was by Mr. Lewis B. Stillwell, Consulting Electrical Engineer, upon Electricity and the Conservation of Energy. He illustrated the function of electricity in the conservation of power resources by interesting figures, showing results accomplished in three typical cases, namely, the plants of the Niagara Falls Power Co., the Northeast Coast Power System at Newcastle-upon-Tyne, and the plants of the Interborough Transit Co., New York. The Niagara plant showed the possibility in water power development

and the Northeast Coast plant the economy resulting from the substitution of large steam-driven units for small steam plants, widely distributed. In the case of the Interborough Company, comparisons were made of the cost under the present system of electrical distribution and of the cost that would have obtained if locomotives had been used instead.

Among the guests at the meeting were Prof. Marsten T. Bogart, President of The American Chemical Society; Dr. James Douglas, Past-Pres. Am. Inst. M. E., and Pres. Phelps-Dodge Co.; John Hays Hammond, Past-Pres. Am. Inst. M. E.; Charles Wallace Hunt, Pres. United Engineering Society, Past-Pres. Am. Soc. M. E.; Charles Kirchhoff, Past-Pres. Am. Inst. M. E., Editor, "Iron Age;" Dr. Albert R. Ledoux, Past-Pres. Am. Inst. M. E.; John W. Lieb, Jr., Past Pres. Am. Inst. E. E., and Vice-Pres. and Asst. Gen. Mgr. N. Y Edison Co.: Dr. W. J. McGee, Secretary Inland Waterways Commission of the U. S. and Soil Expert of the Bureau of Soils; Geo. R. Pegram, Vice-Pres. Am. Soc. C. E., Mech. Engr. Interborough Rapid Transit Co.; Jesse M. Smith, Pres. Am. Soc. M. E.; Geo. W. Tillson, Vice-Pres. Am. Soc. C. E., Ch. Engr. Bureau of Highways, Manhattan.

A STANDARD METHOD OF TESTING REFRIGERATING MACHINES

A standard method of testing refrigerating machines, a preliminary report of which was published in the Proceedings of this Society in April 1907, was presented before the National Refrigeration Congress held in Paris, France, last year, by Dr. D. S. Jacobus, Mem. Am. Soc. M. E., and a member of the committee of this Society appointed for conducting these tests. Professor Jacobus is also a member of the American Society of Refrigerating Engineers, and he has recently called their attention to the report requesting free discussion and honest criticism of the committee's work, insisting that no one should refuse to offer such criticism with the idea that offense would be given. Professor Jacobus voices the opinion that the committee is most anxious to weed out all the weak portions and replace them by something better. He considers that this can be done only by the coöperation of engineers engaged in the refrigerating industry and especially those associated with this Society and with the Society of Refrigerating Engineers.

To aid and facilitate the report of the committee, Professor Jacobus, in a paper presenting the preliminary report to the International Refrigeration Congress in Paris, asked the following questions:

a Is it well to establish a standard set of conditions under which refrigerating machines should be tested, in order that the results obtained for one machine may be compared with those obtained with another?

b Is the standard set of conditions which have been set forth the most desirable to adopt, or could others be employed to advantage?

c Is it well to recommend that the tonnage capacity be based on the actual weight of refrigerating fluid circulated between the condenser and the refrigerator, and actually evaporated in the refrigerator, or would it be better to rely in all cases on the determination of the actual tonnage capacity generated by the machine as given by the actual weight of brine or other liquid refrigerated, and the range of temperature?

d Should the refrigerating capacity of a machine refer only to that part of the plant which has the ammonia or other primarily refrigerating fluid in circulation, or should it include the entire plant and in this way be affected by the capacity of the refrigerator or the refrigerating coils?

e Is the method proposed in the report for weighing the amount of anhydrous ammonia a good one, or would it be preferable to obtain the weight in some other way?

f What is the best method of determining the density of the liquid in an absorption machine? Where the liquid is very rich in ammonia it is impossible to draw it off at ordinary temperatures without allowing considerable of the ammonia to escape in the form of fumes. Would it be a good plan to pass the liquid through a coil placed in a freezing mixture and determine the density at

a much lower temperature than that usually employed and, if so, what temperature would be the best one to adopt?

g What is the best method of determining the purity of the anhydrous ammonia in a machine? In case the amount of moisture is to be determined, can this be done accurately by means of absorption tubes?

h In case water is found to be present in the ammonia, how can this be allowed for in computing the tonnage capacity on the basis of weight of the refrigerating fluid circulated?

i Would it be a good plan to rate refrigerating machines in regard to capacity in some way irrespective of results which may be obtained by tests? For example, would it be advisable to rate ammonia compression machines on the size of ammonia compression cylinders, or the displacement of the piston of the ammonia cylinder, or, on the other hand, should the rating of machines be left entirely to the manufacturers?

He said further in addition to these general questions:

There are a number of other important points that should be carefully considered, and the writer earnestly hopes that the matter will be gone into in a thorough way with a view to establishing a report which will be of value. If a report is not actually used in connection with the work which it outlines it is certainly a failure. The members of this society have use for a report on the subject at hand, and are better able than any other body of men to prepare it in the right way. Let us all pull together and see what we can do in this line in the light of the very latest experience, and establish something which we can conscientiously feel will be of service to the profession at large.

He also suggested the appointment of a joint committee of this Society and the Society of Refrigerating Engineers to consider the necessary rules and to form a report which will represent the careful investigation and judgment of the two societies.

The attention of the members is called to the preliminary report. If they have not the copy of the Proceedings containing this report the Society will be pleased to furnish it upon application. Any suggestions or criticisms sent to the Society will be forwarded promptly to the Committee.

THE LIBRARY

Many new and important books among the recent publications have been added to the Library of the Society.

The Library Committee of this Society, composed of Messrs. John W. Lieb, Jr., H. H. Suplee, Ambrose Swasey, Leonard Waldo, and Chas. L. Clarke, have selected the volumes listed below. These books have been received and catalogued. Of special interest are the reference books, which include many valuable works in English, French and German.

The members are requested to bear in mind that the library is constantly expanding and they are invited to use its resources freely and to encourage those who are not members of the societies to take advantage of its reference books and magazines.

The Library Committee are untiring in their efforts to expand the resources and to extend the usefulness of the Library.

Books

Art of Paper-Making, The, by Alexander Watt.......................... 1907
Boilers, Their History and Development, by H. H. Powles........ 1905
Chemistry of Gas Manufacture, by Harold M. Royle.............. 1908
Concrete, its Uses in Building from Foundation to Finish, by Thomas Potter.. 1908
Cranes, Their Construction, Mechanical Equipment and Working, by Anton Rottcher.. 1908
Experimental Researches of the Flow of Steam Through Nozzles and Orifices, by A. Rateau 1905
Factory Manager, The, by Horace L. Arnold....................... 1905
Flight-Velocity, by A. Samuelson 1906
Flying Machines, by A. W. Marshall and H. Greenley................
Gas Engine Construction, by Henry V. A. Parsell and Arthur Weed....... 1900
Gas Engineer's Laboratory Handbook, The, by John Hornby...... 1902
Gas Power, by F. E. Junge.. 1908
Hydraulics and Its Applications, by A. H. Gibson..................1908
Lathe Design for High and Low-Speed Steels, by John T. Nicolson ... 1908
Leather Manufacture, by Alexander Watt........................ 1906
Manual of Reinforced Concrete and Concrete Block Construction, by Chas. F. Marsh.. 1908
Mercurial Air Pump, The, by Prof. Silvanus P. Thomson............ 1888
Modern Foundry Practice, by John Sharp.......................... 1905
Modern Gas Engines and Producer Gas Plants, by R. E. Mathot... 1906
Modern Power Gas Producers, by Horace Allen.................... 1908
Motor Vehicles for Business Purposes, by A. J. Wallis-Taylor..... 1905
Nitro-Explosives, by P. Gerald Sanford.......................... 1906
Portland Cement, by D. B. Butler.................................. 1905
Practical Design of Irrigation Works, The, by W. G. Bligh........ 1907
Practical Shipbuilding, by A. C. Holmes, vol. 1 and 2.............. 1908
Practical Steam and Hot Water Heating and Ventilating, by Alfred Grant King.. 1908
Profit-Making in Shop and Factory Management, by Chas. U. Carpenter.. 1908
Refrigeration, Cold Storage and Ice-Making, by A. J. Wallis-Taylor. 1902
Resistance of Air and the Question of Flying, by A. Samuelson.. 1905
Steamship Coefficients, Speeds and Powers, by Charles Francis Alexander Fyfe.. 1908
Steam-Turbine Engineering, by T. Stevens and H. M. Hobart........ 1906
Theory, Design, Construction and Use of the Modern Steam Engine by John Richardson.. 1908

Timber, by J. E. Baterden 1908
Tunnel Shields and the Use of Compressed Air in Subaqueous Works by Wm. C. Copperthwaite 1906

REFERENCE BOOKS

Annual Library Index, pub. by N. Y. Publishers Weekly, last volume .. 1908
Atlas of the World's Commerce, by John George Bartholomew 1907
Cyclopedia of the Building Trades, edited by Fred T. Hodgson, vol. 1 to 6 1907
Dictionary of Engineering Terms in English and Spanish, by Andres J. R. V. Garica 1906
Dictionnaire Technique Illustré, in Six Languages, pub. by H. Dunod and et E. Pinat 1908
Greenwood Edgar Classified Guide to Technical and Commercial Books 1904
Handbook on Engineering, by Henry C. Tulley 1907
Poor's Manual of Railroads 1908
Rowell's American Newspaper Directory 1908

MEETINGS OF THE COUNCIL

February 23, 1909

The regular monthly meeting of the Council was held February 23. There were present: President Smith, Messrs. Basford, Bond, Carpenter, Freeman, Humphreys, Hunt, Hutton, Miller, Moultrop, Whyte, Waitt, and the Secretary.

The following deaths were reported: Edwin Reynolds, Past-President; Francis H. Boyer, who was Manager, and Chairman of the Local Committee of the Boston Meeting; R. H. Soule, Charter Member and formerly Manager; Walter M. Allen, George W. Corbin, K. Chickering, William S. Huyette, and Thomas Gray.

The action of the President appointing the following Honorary Vice-Presidents was approved:

To represent the Society at the funeral of Mr. Edwin Reynolds: Messrs. E. T. Adams, F. M. Prescott, E. T. Sederholm, W. J. Sando and James Tribe. To represent the Society at the funeral of Mr. F. H. Boyer; Messrs. G. H. Barrus, F. W. Dean, Gaetano Lanza, G. H. Stoddard and C. J. H. Woodbury.

The resolutions of the Meetings Committee regarding the conduct of The Journal were received and after consideration were referred to the Committee on Advertising in The Journal, consisting of F. R. Hutton, *Chairman*, Geo. M. Basford and the Secretary, for recommendation and report to the Council at its next meeting.

The following resolution from the Meetings Committee was received and referred to a committee of three, to be appointed by the President:

Resolved. That the sanction of the Council be requested to divide the functions of the Meetings Committee relative to the conduct of the annual meetings. That the Meetings Committee shall appoint each year a Chairman who shall select not less than twenty-four assistants, said twenty-five (25) members to constitute a reception committee whose duties shall terminate at the close of the Annual Meeting, that said reception committee shall have sole charge of the collection and distribution of subscriptions for entertainment purposes, and that all entertainment of whatsoever kind, arranged not to conflict with the business and professional sessions, shall be assumed by said reception committee. That the fund so collected shall not in any way conflict with the funds of the Society, and that no expense of any kind relative to entertainment be, as now, a charge against the

cost of conducting the Annual Meeting. That, in case the subscriptions exceed the requirements of the Reception Committee, such excess to be kept in the custody of the Chairman of the Reception Committee; or distributed *pro rata* to the subscribers.

The duties of such committee shall be to consider the general subjects of luncheons, receptions and other entertainments at the annual and semi-annual meetings of the Society; the methods to be followed in arranging for each and the source of funds to cover the necessary expenses of each. This committee will report to the Council at its next meeting.

The following resolutions of the Meetings Committee were adopted as amended:

Resolved. That the Meetings Committee may arrange, subject to the approval of the Council, authorize and discontinue, as in the judgment of the Meetings Committee may be for the best interests of the Society, with members of the Society residing in other places, as is now done monthly in New York, for the presentation and discussion of such papers as may have been previously accepted by the Meetings Committee. The proceedings of such meetings to be reported stenographically, transcribed and sent promptly to the Meetings Committee. The expenses of such meetings to be defrayed by the Society on a basis prearranged with the Meetings Committee; such expenses to be under the control of the Executive Committee of the Council by approval in general, before such expenses are incurred.

Amendment, Rule 2. Upon the recommendation of the President and the Secretary, Rule 2 was amended, eliminating the numbering of badges. As amended and adopted it will read:

R2 The Secretary shall provide a badge or pin for each member or guest attending the annual and semi-annual meetings; the badge of each Member, Associate and Junior to bear his name.

Voted. That the Council authorize the issuance of Professional Records twenty days, instead of thirty days, previous to the issuance of the ballot for the Spring Meeting of 1909.

Conservation Meeting. The Secretary reported the arrangement of the Committee on Conservation of Natural Resources under the auspices of the four national engineering societies for a meeting of the engineering profession to be held on the evening of March 24.

Thurston Memorial. The Chairman of the Thurston Memorial Committee reported the decision of the committee to award to H. A. McNeil the contract for the installation of a bronze replica of the Thurston Memorial, which was installed at Cornell University in June 1908, of which Mr. McNeil was the sculptor. This memorial will be placed in the hallway leading to the rooms of the Society, on the wall opposite the elevators.

Committee on Affiliated Societies. The Committee reported a basis of relation with other societies desiring affiliation with this Society which was approved in principle in the Council and referred to a Special Committee to consist of Messrs. Jesse M. Smith, President, F. R. Hutton and R. C. Carpenter, to perfect details and report to the Council.

It was voted that the Committee on Affiliated Societies be discharged with thanks.

Student Branches. The Secretary reported requests for permission to form student branches which were referred to the Executive Committee for recommendation and report.

The John Fritz Medal Committee. Prof. F. R. Hutton, Honorary Secretary, reported the action of the John Fritz Medal Committee in awarding the medal this year to an Honorary Member of the Society, Mr. Charles T. Porter. A Special Committee, of which Past-President Henry R. Towne is Chairman, and the Honorary Secretary, were appointed to arrange for suitable presentation exercises.

I. E. Moultrop, Member of the Council, asked information respecting the general subject of meetings of members of the Society in Boston. It was the sense of the Council that the holding of meetings by members of the Society in other cities than New York be encouraged and that this communication from Mr. Moultrop be referred to the Meetings Committee for action in accordance with the resolutions that the Committee adopted at this meeting of the Council.

Council adjourned to meet on March 9, at 3.30 p.m.

March 9, 1909

The regular monthly meeting of the Council was held on Tuesday afternoon, March 9, in the rooms of the Society. There were present, Mr. Jesse M. Smith, President, and Messrs. Bond, Carpenter, Gantt, Hunt, Hutton, Miller, Moultrop, Riker, Stott, Waitt, Whyte and the Secretary.

Executive Committee. The action of the Executive Committee in approving the names of candidates for membership in the Society as offered by the Membership Committee was confirmed.

House Committee. The report of the House Committee was approved, recommending the rearrangement of the rooms of the Society, placing the Secretary in the room adjoining the reception room. Upon the recommendation of the Chairman of the Finance Committee the Council approved an appropriation of $50 for the nec-

essary changes in the partitions to effect the above change, and $100 for plates on the pictures, models and historical relics in the possession of the Society.

Library Committee. The Library Committee reported the purchase of new books to the extent of $260.

Special Committees. The special committee appointed under date of February 16, at a meeting of all of the standing committees of the Society with the Executive Committee, to consider the possible relation between the several committees of the Society and the Finance Committee, with respect to the responsibilities of each in the financial administration, recommended a change of the standards of the Society, simplifying the work; the reading of the report was considered as a notice under By-Law 44 leading up to the proposed change, to be voted on at the next meeting of the Council.

Student Branches. The Executive Committee recommended that the Council grant the privilege of Student Branches to the following institutions: Armour Institute of Technology, Chicago, Ill.; Leland Stanford Jr. University, Palo Alto, California; Polytechnic Institute, Brooklyn, N. Y.; State Agricultural College, Corvallis, Oregon; Purdue University, Lafayette, Ind.; University of Kansas, Lawrence, Kan. The Council thereupon approved the recommendation. The Executive Committee offered a set of rules for the guidance of the Secretary in the conduct of this work, and after consideration they were referred back to the committee for further consideration.

Hudson-Fulton Celebration. The President reported on the Hudson-Fulton Celebration the decision of the conferees of the National Engineering Societies, not to hold a loan exhibition, but that instead they were favorably disposed to the installation of a bronze tablet commemorative of Fulton's achievement.

Mr. Stott, Chairman of the Committee on Conservation of the American Institute of Electrical Engineers, announced that there would be a meeting of the Engineering Profession under the auspices of the four National Engineering Societies, on the evening of March 24, on the subject of the Conservation of our Natural Resources.

Voted. That the appropriation of $150 approved by the Finance Committee to cover various expenses already incurred during the year on the subject of conservation, and the additional expenses incident to the participation of the Society in the above meeting, be approved.

Moved by Mr. Miller and seconded by Professor Hutton, that the Committee on Conservation of this Society be instructed to give wide publicity to the meeting of March 24, and after the meeting to give wide publicity to the proceedings of that meeting; it was further

requested that the expenses provided for in this resolution be charged against the meeting.

Voted. That a special appropriation of $100 be made for this purpose, subject to the approval of the Finance Committee.

Involute Gearing. The Secretary read a letter from Mr. P. V. Vernon, member of the Society, Chief Engineer of Alfred Herbert, Ltd., machine tool makers, Coventry, England, to the effect that he proposes that the Institution of Mechanical Engineers and The American Society of Mechanical Engineers coöperate in the matter of a standard for involute gearing.

Voted. To refer the matter to the Committee to be appointed on this subject.

Relations With the Public. Moved by Mr. Miller and seconded by Mr. Gantt, that the President be requested to appoint a committee of three members to prepare and present at the Washington Meeting a report upon the Relation of the Society to the Public. This action to be in accordance with the resolution presented by Mr. Ambrose Swasey and adopted by a vote of the Society at the last annual meeting of the Society, December 1908, which resolution was the result of a paper presented by Mr. Morris L. Cooke on The Engineer and the People.

The following Committee was thereupon appointed by the Council and approved: Messrs. Ambrose Swasey, Morris L. Cooke and the Secretary.

A communication from the United Engineering Societies was received to the effect that the available offices in the building did not exceed one-third of an office floor, and the Society was asked if they had any space which could be given for the use of the sister societies. The Secretary was instructed to respond that the Society had no space unoccupied, and did not desire to release any.

Amendments. By-Laws 27 and 28, also By-Law 17. Notice was given under the requirements of C59 that it is proposed at the next meeting of the Council to vote on amendments to By-Laws 27 and 28 governing the duties of the Library and House Committees, and By-Law 17 to agree with By-Law 14 on requirements and procedure of voting; also of certain changes in the standards in accordance with B44.

American Society of Testing Materials. The request of the American Society of Testing Materials for the appointment of a delegate to an international conference was referred to the Executive Committee with power.

Council adjourned to meeting on April 13, 1909.

NECROLOGY

FRANCIS H. BOYER

Francis H. Boyer died at his home, Somerville, Mass., February 21, 1909. He was born at Manheim, N. Y., in 1845, and at the age of ten years went to Greensburg, Ind., where he remained until he was 18 years old. He learned the trades of millwright, carpenter and architect. On his return to the East he entered the steamboat transportation business in Brooklyn, in which he was engaged during the Civil War.

At the age of 23, he went to the frontier, settling at Seneca, Nemeha Co., Kan., where he carried on a stock and land business for a few years. He then returned to Brooklyn and engaged in the refrigerator building business, and was associated with the building of the first ship refrigerator for carrying beef to Europe. He eventually became superintendent of the De La Vergne & Mixer Co., refrigerator builders, directing the construction of machinery for brewery refrigerators. Mr. Boyer built the first brewery refrigerator in Boston in 1884. His work called him to Washington, Baltimore, Newark and New York. He settled in Boston in 1890, and was appointed master mechanic of the John P. Squire Co. He designed the big chimney at that company's plant in East Cambridge and remained with the company until its assignment in 1900, when he went into business for himself, with his son as a member of the firm.

Mr. Boyer was a Manager of this Society, 1899–1902, and was chairman of the Local Committee at the time of the meeting of the Society in Boston in 1902. He also did important work on the Committee of the Society for Determining Standard Methods for Conducting and Reporting Steam Engine Trials. He was a member of the Boston Society of Civil Engineers; the American Society of Refrigerating Engineers; honorary member of the National Association of Stationary Engineers; Somerville Council, Royal Arcanum. He was President of the Somerville Board of Trade for two years.

GENERAL NOTES

COLUMBIA UNIVERSITY

The Department of Mechanical Engineering of Columbia University, of which Dr. Charles E. Lucke is the head, has developed a feature of the greatest benefit to students by selecting men engaged in active work to give lectures on their specialties. The lectures are based on outlines prepared by the faculty and are a part of the regular work of the engineering students in their third and fourth years.

The course is being conducted by Fred J. Miller, Vice-Pres. Am. Soc. M. E., Elmer Neff, Mem. Am. Soc. M. E., Brown & Sharpe Co., Hugh Aikman, J. H. Williams Co. (Drop Forgings), D. B. Bullard, Machine Tool Co., C. E. Coolidge, Niles-Bement-Pond Co., Geo. Jeppson, Norton Co., Chas. H. Norton, Norton Co. Classifications are as follows:

Elevating and Conveying Machinery, with special reference to economic handling of materials by mechanical means; conducted by Lincoln DeGrott Moss, Consulting Engineer, New York, as representative of seven of the prominent manufacturers of this class of machinery.

Pumping Machinery: lecturers not yet selected except that Mr. Louis Doelling of the Schutte & Koerting Co. will take up jet types.

Air Machinery, including compressors, fans, blowing engines, air lifts, pipe lines and compressed air apparatus, conducted by Mr. Fred W. O'Neil, of the Nordberg Co.

Refrigerating and Ice Making Machinery, by Mr. Fred Ophuls of the De La Vergne Machine Co.

In the fourth year the following courses are conducted with the assistance of outside experts:

Steam Turbines, by Messrs. Callan and Stone and Dr. Loewenstein, all of the General Electric Co.

Manufacturing Plant Design, by Mr. Chas. Day, Dodge & Day Co., Mr. Henry Hess of the Hess-Bright Co., Mr. H. W. Wharton of the Land-Wharton Co., Mr. H. F. Stimson, of the Emerson Co.

Works Management, by Mr. Chas. V. Going, of the *Engineering Magazine*, Mr. C. U. Carpenter, of Herring-Hall-Marvin Safe Co., Mr. R. T. Lingley, Certified Public Accountant, Mr. Harrington Emerson, of The Emerson Co., Mr. J. N. Gunn, of Gunn-Richards & Co.

Water Power Machinery, by Mr. N. M. White of the I. P. Morris Co.

UNIVERSITY OF ILLINOIS

The United States Geological Survey, in coöperation with the State Geological Survey, has established at the College of Engineering, University of Illinois, Urbana, a Mine Explosion and Mine Rescue Station. The purpose of the station is to interest mine operators and inspectors in the economic value of such modern appliances as oxygen helmets and other resuscitation apparatus as adjuncts to the normal equipment of mines. The station also will concern itself with the training of mine bosses and others in the use of such apparatus.

The formal opening of the station constituted a part of the proceedings of a Fuel Conference, held at the University of Illinois, March 11 to 13, under the auspices of the Technologic Branch, U. S. Geological Survey, of the Illinois Geological Survey and of the College of Engineering. On March 11, the rescue station was formally opened with addresses by Pres. E. J. James, University of Illinois; Prof. J. A. Holmes, Mem. Am. Soc. M. E., U. S. Geological Survey; Mr. A. J. Moorshead, Illinois coal operators; Mr. T. L. Lewis, United Mine Workers. There were demonstrations of the use of oxygen helmets and resuscitation work. Addresses were made on the prevention of mine explosions; smoke suppressions and economy in the use of fuels; the fuel resources of the country, etc.

STEVENS INSTITUTE OF TECHNOLOGY

At the annual alumni dinner of Stevens Institute of Technology, held at the Hotel Astor, New York, February 19, President Humphreys, Mem. Am. Soc. M. E., announced that at the next meeting of the Board of Trustees of Stevens Institute, the following new trustees would be elected: Dr. H. S. Pritchett, President of the Carnegie Foundation for the Advancement of Teaching; Mr. John Aspinwall; Dr. D. S. Jacobus, Mem. Am. Soc. M. E.; Mr. Anson W. Burchard. Mem. Am. Soc. M. E.

THE NEW PRESIDENT OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Prof. Richard C. Maclauren, formerly professor of the Mathematical Physics, Columbia University, has been called to the presidency of Massachusetts Institute of Technology.

Professor Maclauren was born in Edinburgh, Scotland, in 1870. He entered the University of Cambridge in 1892, graduating with the degree of B.A. in 1895, and receiving the degree of M.A. the following year. In 1898, he received the degree of Sc.D. from the same university and in 1904 the degree of LL.D. In his work for the master's degree he gained the highest possible rank in the most advanced examination in mathematics given at Cambridge, and he received the Smith prize for his thesis on a mathematical subject. After graduation, he was elected a fellow of St. John's College, Cambridge.

He made a study of educational institutions in the United States and Canada and after concluding the investigations he returned to the University of Cambridge and took up the study of law, receiving the McMahon law scholarship. His thesis, The Title to Realty, which was afterward published in English and French, was awarded the Yorke prize. Dr. Maclauren spent several months in study at a German University and in 1898 was appointed Professor of Mathematics at the University of New Zealand. He later became a Trustee of the institution. In 1903 he was made Dean of the Faculty of Law and resigned this work to accept the appointment to the chair of mathematical physics at Columbia University, in 1907. He has written a book on physical optics, the first volume of which was published in February of last year. He has written a number of papers for scientific magazines; a recent contribution on Higher Technical Education in the United States, which appeared in the *Revue Scientifique* describes the Massachusetts Institute of Technology as the typical American technical school.

THETA XI FRATERNITY

Among those who made addresses at the forty-fifth annual convention of the Theta Xi fraternity in New York, February 19–20, were Onward Bates, President, Am. Soc. C. E., and Samuel Higgins, General Manager, N. Y. N. H. & H. R. R. Wm. H. Wiley, Mem. Am. Soc. M. E., presided at the convention, and Messrs. J. A. Knighton and H. W. Hodge conducted an excursion to inspect the Blackwell's Island Bridge.

RETIREMENT OF PROF. RICHARDS

Prof. C. B. Richards, Professor of Mechanical Engineering, Sheffield Scientific School of Yale University, since 1884, has retired from active service in the University, having reached the age limit of 65 years. Professor Richards' retirement takes effect on the close of the university year at which time he becomes Professor Emeritus.

Prof. Lester Paige Breckenridge, head of the mechanical engineering department of the University of Illinois since 1893, has been appointed Professor of Mechanical Engineering at Sheffield Scientific School, Yale University, to take up his duties in September 1909. Professor Breckenridge was born in Meriden, Conn., May 17, 1858, and was graduated from Sheffield Scientific School 1881. He was instructor in mechanical engineering and was engaged in general engineering work at Lehigh University until 1891. From 1891 to 1893 he was professor of mechanical engineering and director of shops of Michigan Agricultural College at Lansing, Mich.; from 1893 to date, professor of mechanical engineering at the University of Illinois, Urbana, Ill.; and from 1905 to date, director of engineering experiment station, University of Illinois.

Prof. Lionel S. Marks, Mem. Am. Soc. M. E., has been promoted to Professor of Mechanical Engineering at Harvard University. He was educated in King Edward VI School, and Mason College, Birmingham, England, receiving the degree of M.E. in 1891, and the degree of B.S. in 1892 from the University of London, and from Cornell University the degree of M.M.E. in 1894. From the latter date until the present he has been instructor in thermodynamics and assistant professor of mechanical engineering at Harvard, in charge of the engineering laboratories. Professor Marks has also been engaged in consulting and testing work.

STUDENT BRANCHES

The need for establishing student branches of the Society has been shown by the number of applications to form such branches which have been received from technical institutions.

The Council at its meeting March 9 granted permission to form student branches, to the Armour Institute of Technology, Leland Stanford Jr. University, Polytechnic Institute of Brooklyn, State Agricultural College of Oregon, Purdue University, and University of Kansas.

COÖPERATION OF THE AMERICAS

At the Pan-American Scientific Congress, held in Santiago, Chili, in December 1907, the following resolutions were adopted and transmitted to this Society by Dr. L. S. Rowe, Chairman of the Delegation to the Congress from the U. S. and Professor of Political Science at the University of Pennsylvania. We quote in full Dr. Rowe's letter which contained the resolutions.

Delegation of the United States of America to the Pan-American Scientific Congress

Santiago, Chile, January 7, 1909.

L. S. Rowe, *Chairman.*

The American Society of Mechanical Engineers
Calvin W. Rice, Sec., 29 W. 39th St., New York

Dear Sir:

At a meeting held during the first week in January, of the Delegates from the United States to the Pan-American Scientific Congress, the following resolution was adopted:

"Resolved, That this Delegation officially bring to the attention of the learned societies of National scope in the United States the desirability of inviting the scholars and investigators of Latin-America to coöperate with them."

In accordance with this resolution it is my duty to assist you to lay the matter before The American Society of Mechanical Engineers for consideration.

In the opinion of the Delegation the inviting of the scholars and investigators of Latin-America to participate in the annual meetings of your Society would greatly tend to promote mutual friendship between North and South America. It has often been difficult in the past to secure intercommunication between scientists in the two Americas who are interested in similar subjects. It is felt that if it were possible to secure the attendance at your meetings of representatives from Latin-America, or to obtain papers from them, to be read in the appropriate sections of your annual meetings, an important step forward would be made toward enlarging the opportunity for North American specialists to exchange ideas with those of South America. Although the objects of the suggested coöperation may be achieved in a greater or lesser degree by means of the triennial Pan-American Scientific Congresses (the next of which is to meet in Washington in October 1912) our experiences in Santiago have led us to believe that the plan suggested herewith will prove to be of great practical value.

If your association decides to invite the coöperation of the scholars and investigators of Latin-America, the chairman of the delegation will be very glad to be of any possible assistance, or to endeavor to obtain the names of such Latin-American scientists as might most acceptably serve the purposes of your association.

Yours very truly,
(Signed) L. S. Rowe, *Chairman.*

The Congress mentioned was the first Pan-American and was held under the auspices of the government of Chili. Questions of interest to South, Central and North America were discussed, and universities, scientific societies, South American and foreign corporations were represented.

NORTH AMERICAN CONSERVATION CONFERENCE

The North American Conservation Conference, which was held in Washington, February 18, 1909, has published a Declaration of Principles in regard to forests, lands, minerals and the protection of game.

The Conference agrees that the conservation movement tends strongly to develop national efficiency in the highest possible degree; that to accomplish such an object with success, the maintenance and improvement of public health is the first essential, and that in all steps for the utilization of natural resources considerations of public health should be kept in view.

The Conference recognizes that the forests are indispensable to civilization and public welfare, and regards their wise use, effective protection and renewal, as a public duty, devolving upon all forest owners, public, corporate or individual.

The land they declare to be a fundamental resource, yielding the materials needed for sustaining population and forming the basis of social organization. The special need is to promote productivity. They favor the possessing of the land by the men who live upon it, not only as promoting such productivity, but also as the best guarantee of good citizenship.

The mineral resources are recognized as forming the chief basis of industrial progress and as playing an indispensable part in our modern civilization. Their use and conservation are regarded as essential to the public welfare. The Conference favors action by each government looking towards reduction of the enormous waste in the exploitation of such fuels, and directs attention to the necessity of an inventory of this resource.

The preservation of game and the protection of bird life, they declare to be intimately associated with the conservation of natural resources, and favor game protection under regulation, the creation of extensive game preserves, and the special protection of such birds as are useful to agriculture.

They regard the action of the President of the United States, in calling a conference to consider the conservation of the natural

resources of North America, as in the highest degree opportune, and believe the proceedings of the conference and the information mutually communicated by the representatives assembled to have been conducive to the best interests of the countries participating. They recommend the establishment in each country of a permanent Conservation Commission, and through these several commissions a system of intercommunication whereby all discoveries, inventions, processes, inventories of natural resources, seeds, seedlings, new or improved varieties, and other material of value in conserving or improving a natural resource, shall be transmitted by each Commission to all of the others.

The Commissioners representing the United States, the Dominion of Canada, the Republic of Mexico and the Colonies of Newfoundland, signed a statement on February 23, 1909, addressed to the President of the United States, and expressing their belief that the Conservation of Natural Resources is a problem world-wide in scope, and that therefore all nations should be invited to join in a conference on the subject of world resources, their inventory, conservation and wise utilization.

The Conference was attended by Professor Swain, Chairman of the Committee of this Society on the Conservation of Natural Resources.

THE NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION

The National Society for the Promotion of Industrial Education, of which Dr. Alex. C. Humphreys, President of Stevens Institute of Technology, and Mem. Am. Soc. M. E., is president, has issued a letter inviting interest in its membership and giving a brief summary of its purpose and the work accomplished. An extract states:

> The organization exists to further in every way the movement to better industrial training and its members are in every State in the union. It represents no special class; its meetings and publications form an open forum wherein the opinions of all parties may be frankly expressed.
>
> The very serious need for industrial education is evident in many quarters. Knowledge of the movement is equally important to employers, employees and school officers. By identifying yourself with the national society, you will aid in the work which the society represents, you will be in touch with its continued development, and you will secure important contributions to the literature of industrial education.

THE LOUISIANA ENGINEERING LAW

The Louisiana State Legislature has passed a bill to regulate the practice of Civil Engineering and Surveying in Louisiana, and appointed a Legislative Committee to guard its interests.

The bill originated in the Louisiana Engineering Society, and provides for the regulation and the practice of Civil Engineering and Surveying; creates a State Board of Engineering Examiners, and regulates their fees and emoluments The purpose of the law is to prevent the practice of the civil engineering or surveying by unauthorized persons; and to provide for the trial and punishment of violations of the law by fine or imprisonment.

The law provides that no person except those already engaged in this practice of civil engineering under the existing engineering and surveying laws of the State shall practice the profession unless such person possesses all the requirements of the law.

After the passage of the act, any person entering upon the practice of civil engineering or surveying shall present to the Board of Engineering Examiners a diploma from an engineering school of good standing, or pass a satisfactory examination. For Surveying: Geometry, Trigonometry, Land Surveying, Practical Use of Instruments. Civil Engineering: the same as surveying with the addition of Natural Philosophy or Physics.

The applicant must be at least twenty-one years of age, of good moral character, and possess at least a primary education.

The Board of Engineering Examiners is to consist of five members; all must be practicing civil engineers or surveyors. The Board shall be appointed by the Governor of the State from a list presented by the Louisiana Engineering Society.

OTHER SOCIETIES

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The American Institute of Electrical Engineers celebrated on March 11 the twenty-fifth anniversary of their organization. The celebration took the form of a dinner at the Hotel Astor.

The decorations were a remarkable exhibition of electrical display, the plants and flowers being illuminated from below through cut crystal. The Rialto, the Grand Canal, and the Cathedral Campanile of St. Mark were reproduced, the Cooper-Hewitt light affording an illumination which made the scene remarkably realistic.

Messages were read from Alexander Graham Bell, inventor of the telephone; from Thomas A. Edison, inventor of the incandescent lamp; from the Institution of Electrical Engineers, London; La Société Internationale des Electriciens, Paris, and Der Verband Deutscher Elektrotechniker, Berlin.

Three hundred and fifty members and guests were present. Louis A. Ferguson of Chicago, President of the Institute, was toast master; Jesse M. Smith, President of Am. Soc. M. E., gave an address of greeting from the sister societies; and other addresses were made by Elihu Thomson and Frank J. Sprague, past-presidents of the Am. Inst. E. E., and by Dr. Alex. C. Humphreys, President of Stevens Institute of Technology.

At the meeting of the American Institute of Electrical Engineers, March 12, the secretary announced that 113 associates had been elected and 5 associates transferred to the grade of member. The following list of nominees was made by the board of directors for officers to be elected this spring; President, Lewis B. Stillwell; Vice-presidents, John J. Carty, Paul M. Lincoln, Paul Spencer; Managers, A. W. Berresford, W. S. Murray, H. H. Norris, S. D. Sprong; Treasurer, George A. Hamilton; Secretary, Ralph W. Pope.

Barton R. Shover, Electrical Engineer of the Indiana Steel Company of Gary, Ind., presented a paper entitled The Industrial Application of the Electric Motor, as illustrated in the Gary Plant of the Indiana Steel Company. The paper was illustrated with lantern

slides and was discussed by Messrs. B. A. Behrend, Gano Dunn, D. B. Rushmore, W. T. Dean, Robert Hull, Brent Wiley, L. A. Ferguson, and B. R. Shover.

The American Institute of Electrical Engineers cordially invite the members of this Society to attend the meetings of the Institute wherever held. The invitation covers the branches of the Institute which hold frequent meetings at different points in the country. This is an opportunity, afforded to members of the Society in New York and elsewhere, which they will doubtless find offers much of pleasure and profit, and it is hoped that the members will avail themselves of this kindness on the part of the A. I. E. E.

AMERICAN ELECTROCHEMICAL SOCIETY

The annual meeting of the American Electrochemical Society is to be held at Niagara Falls on May 6, 7 and 8. Papers will be presented by Gustave Gin of Paris and by Dr. Kjellin, the inventor of the Kjellin furnace. A paper on the Héroult steel furnace is expected from Mr. Robert Turnbull.

AMERICAN SOCIETY OF CIVIL ENGINEERS

At a meeting held on March 3, two papers were presented for discussion. They were, The Action of Frost on Cement and Cement Mortar, together with other Experiments on these Materials, by Messrs. Ernest R. Matthews and James Watson, and The Bonding of New to Old Concrete, by Mr. E. P. Goodrich.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS

A number of Hungarian Engineers and Architects pursuing their professions in this country have organized the American Society of Hungarian Engineers and Architects. The society has two objects: first, to bring in closer touch engineers and architects of Hungarian extraction, living in this country, and to give moral support and information to newcomers; second, to encourage the exchange of engineering, technical and industrial information between the technical men of Hungary and of the United States and to foster technical societies, sciences and industries.

The society will hold monthly meetings when papers will be read and discussed. The membership consists of mechanical, electrical

and civil engineers, chemists, architects and craftsmen. The officers of the new society are as follows: President, A. Henry Pikler; Vice-President, Karoly Z. Horvay; Secretary, Zoltan de Németh; Treasurer Sandor Oesterreicher; Assistant Secretary, Ernest L. Mandel. The society's business address is Box 1031, New York.

WASHINGTON SOCIETY OF ENGINEERS

At the meeting of the Washington Society of Engineers, February 16, Mr. Van H. Manning, topographer of the U. S. Geological Survey, gave an illustrated lecture on the overflow lands in the Yazoo Delta, which outlined the preliminary investigations now being made by the U. S. Geological Survey in coöperation with the State of Mississippi, leading to the reclamation of 7000 square miles extending south along the Mississippi River from a point ten miles south of Memphis.

Following this lecture, the society gave an informal reception to the engineers, who accompanied President-elect Taft to Panama: Frederic P. Stearns; John R. Freeman, Mem. Am. Soc. M. E.; Isham Randolph; Capt. Charles P. Allen; Allen Hazen; James D. Schuyler; Arthur P. Davis. Other guests were W. H. Code, Chief Engineer, Indian Reclamation; L. C. Hill, Supervising Engineer, U. S. Reclamation Service; Marsden Manson, City Engineer, San Francisco; C. E. Grunsky, Consulting Engineer, New York; W. B. Matthews, Chief Counsel, Los Angeles Aqueduct Commission.

BOSTON SOCIETY OF CIVIL ENGINEERS

The Boston Society of Civil Engineers had its regular monthly meeting on February 17.

A paper presented by Mr. H. M. Haven, Refrigerating Engineer with Mr. F. W. Dean, Mem. Am. Soc. M. E., reviewed briefly the general theory of refrigeration and the various types of refrigerating apparatus using ammonia as a refrigerant.

The many modern applications of refrigeration were taken up in some detail, including plate and can ice-making, the preservation of food in refrigerated warehouses, pipe-line refrigeration, fish freezing, packing-house refrigeration, storage of furs and fabrics, tunneling, hospital and auditorium cooling, the cooling of chocolate factories, the use of chilled air in the transportation of fruit, and refrigeration as applied to the air supply of blast furnaces.

The paper was fully illustrated by lantern slides.

NEW ENGLAND ASSOCIATION OF GAS ENGINEERS

The New England Association of Gas Engineers held their annual meeting on February 17 and 18, at Young's Hotel, Boston, Mass.

The following papers and topics were discussed: Street Lighting, Edwin Garsia; Tar for Roads, Charles P. Price; A Comparison of the Enriching Values of Benzol and Gas Oil, L. J. Willien; Some Results of the Use of Steam and Air Meters in the Water Gas Plant, R. E. Wyant; The Comparative Practical Efficiency of Various Types of Gas Lamps, R. C. Ware; Why the Gas Man should be an Illuminating Engineer, Norman Macbeth; Calorimetry, J. B. Klumpp.

All the officers were reëlected for the coming year, as follows: President, W. G. Africa; Vice-Presidents, W. H. Snow, B. J. Allen; Directors, D. D. Barnum, Thomas H. Hintze, C. A. Learned, J. A. Coffin, H. K. Morrison; Secretary and Treasurer, Nathaniel W. Gifford.

NEW YORK RAILROAD CLUB

The meeting of the New York Railroad Club of February 19 was occupied chiefly with a paper by Col. B. W. Dunn, on The American Railway Association's Bureau for the Safe Transportation of Explosives and Other Dangerous Articles. This paper was discussed by W. G. Besler, H. F. Allen, N. D. Maher, and Dr. C. B. Dudley, Mem. Am. Soc. M. E.

A Committee appointed at a previous meeting reported a testimonial to Mr. Herbert H. Vreeland, Past-President of the club, which is to be engrossed and framed, and presented to Mr. Vreeland in recognition of the long and valuable service he rendered the club as its chief executive.

TECHNICAL SOCIETY OF BROOKLYN

In the regular bi-monthly meeting of the Technical Society of Brooklyn, on February 19, Mr. F. F. Grevatt read a paper on Electrical Power Transmission, written by Mr. Henry Pikler. A general discussion elicited some interesting information on practical results in connection with the more theoretical features of the lecture.

Following up this subject, J. P. Freund, in the society's meeting on March 5, lectured on Demonstrations and Effects of Electricity, with special reference to wireless telegraphy. The paper was discussed by Mr. Wm. Kajerdt and Dr. Adolph Maeusert.

ENGINEERING SOCIETY OF WISCONSIN

The organization of the Engineering Society of Wisconsin was completed at the first meeting held at the University of Wisconsin, February 24–26. The officers elected were: President, Dean F. E. Turneaure, University of Wisconsin, College of Engineering; Vice-President, McClelland Dodge; trustees for two years, B. F. Lyons and E. P. Worden; trustees for one year, E. Gonzenbach and E. R. Banks.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

On Wednesday evening, February 24, 1909, at the Technical School Hall, Providence, R. I., Mr. Walter Massie of the Massie Wireless Telegraph Co., delivered a lecture on the subject of wireless telegraphy. He gave a brief history of the discovery and improvement of wireless telegraphy, thoroughly explaining the important events since 1888. The lecture was illustrated by sketches on the blackboard and by working apparatus. A transmitting receiving system was set up on the stage and the process of sending and receiving messages was explained and demonstrated.

ROCHESTER ENGINEERING SOCIETY

The regular monthly meeting of the Rochester Engineering Society which was to be held on February 12 was postponed until February 26. At this meeting, Mr. Stephen P. Cobb presented a paper on The Artificial Gas Industry of the Present Day, which was illustrated by lantern slides.

WESTERN SOCIETY OF ENGINEERS

At the March 3 meeting of the Western Society of Engineers, Mr. John M. Ewen presented a paper on the subject, The Chicago Harbor and River.

BLUE ROOM ENGINEERING SOCIETY

The subject under discussion at the March 4 meeting of the Blue Room Engineering Society was The Mechanical Equipment of the Singer Building, by Mr. Charles G. Armstrong. During the course of the lecture, which was illustrated with lantern slides, Mr. Armstrong described the design and construction from the sinking of the first caisson to the unfurling of the flag at the peak of the pole.

COLORADO SCIENTIFIC SOCIETY

At the March 6 meeting of the Colorado Scientific Society, Mr. Victor G. Hills read a paper on Tungsten, showing a map of the Boulder County fields. This was followed by a paper by Mr. Henry E. Wood entitled Notes on Magnetic Separation as Applied to Tungsten Ores.

NEW ENGLAND WATER WORKS ASSOCIATION

At the meeting of the New England Water Works Association held at the Hotel Brunswick, Boston, Mass., March 10, an address on Civil Service in its Application to the Water Department, was given by Hon. Joseph C. Pelletier of the Massachusetts State Civil Service Commission. This was followed by a description of work in progress for the New York Board of Water Supply, and Mr. J. Waldo Smith, Mem. Am. Soc. M. E., Chief Engineer of the Board, and Mr. Carroll F. Story, presented a paper on The Ludlow Filters.

FRANKLIN INSTITUTE

The meeting of the Franklin Institute, March 11, was devoted to a lecture by Dr. A. S. McAllister of New York on Power Factor and Commutation Conditions in Single Phase Series Motors, showing how the difficulties heretofore existing in this type of motor have been practically overcome.

OHIO ELECTRIC LIGHT ASSOCIATION

The Ohio Electric Light Association will hold its annual convention in Toledo, Ohio, July 13–15. The program will include the following topics: The Titanium Arc Lamp, Reports and Discussion on Tungsten Lamp Experience; The Supply of Current for Lighting, to other Towns from a Centrally Located Station; Report on Methods of Lamp Renewals; Commercial Organization of an Electric Light Company and its Relation to the Public; Factors Determining the Prices to be Charged for Street Lighting.

INDUSTRIAL EXPOSITION AT CLEVELAND, OHIO

Cleveland's Industrial Exposition will be held June 7 to 19, in Central Hall. A temporary exposition building has been erected diagonally across the street; the area of the two halls will be 14,655 sq. ft. The exhibits include the latest types of street cars and range from ponderous machinery to the intricate products of expert workmanship.

CLEVELAND ENGINEERING SOCIETY.

At the regular meeting of the Cleveland Engineering Society, March 9, 1909, Mr. George R. Shepard read a paper on Some Engineering Problems in Connection with the Niagara Power Development. Among the discussors of this paper were Messrs. Roberts, Mordecai, McKinnon.

PERSONALS

Mr. W. L. Abbott has been reëlected president of the board of trustees of the University of Illinois.

Mr. L. P. Alford has contributed an article on An Analysis of 5500 Machine-shop Accidents, to the February 11 issue of *The American Machinist.*

Mr. George M. Basford has contributed an article on Railway Business Association—an Inside View, to the February 6 issue of *The Railway and Engineering Review.*

An extract of The Application of Low-Pressure Turbines to Power Generation, by Mr. James R. Bibbins, read before the Canadian Society of Civil Engineers, Montreal, Que., was published in the March first number of *The Practical Engineer.*

Mr. Sterling H. Bunnell has contributed an article on The Problem of the Small Refrigerating Machine to the March issue of *Cassier's Magazine.*

Mr. A. G. Christie has issued a book on The Steam Turbine.

Mr. Frank M. Coffin has entered the employ of the Maintenance Co., New York, in the capacity of Superintendent of Construction and Repairs. He was until recently in the construction department of the Otis Elevator Co., New York.

The Status of the American Motor Car, by Mr. Howard E. Coffin, appeared in the February issue of *The Gas Engine.*

Mr. William C. Coffin, until recently president of the Coffin McKean Co., Pittsburg, Pa., has become connected with the Jones & Laughlin Steel Co., Pittsburg, Pa., in the capacity of Structural Engineer.

Mr. Charles Day has given a series of lectures on Designs for Manufacturing Plants, under the direction of the mechanical engineering department of Columbia University.

Mr. Henry L. Doherty has contributed an article on the benefit of Exhibits and their Effect on Commercialism to the March first issue of *Progressive Age.*

Mr. Geo. W. Dunham has resigned as Chief Engineer of the Olds Motor Works to accept a similar position with the Hudson Motor Car Co. of Detroit.

Mr. Charles E. Eaton, of the firm of Eaton & Brownell, Watertown, N. Y., has prepared the plans and specifications for the largest talc mill in the world, near Hailesboro, N Y. This was erected for the International Pulp Company.

Mr. H. P. Fairfield has an article, A Planer with Elaborate Ornamentation in the March issue of *Machinery*.

Mr. Walter Ferrier, Assistant to General Superintendent, Carnegie Steel Co., has been transferred to the Schoen Steel Wheel Plant, McKees Rocks, Pa.

Mr. H. D. Fisher is no longer connected with Arthur D. Little of Boston, Mass. He has entered the employ of the U. S. Glass Co., of Pittsburg, as Supervising Engineer.

Mr. Floyd W. Frederick has accepted a position on the engineering staff of the National Board of Fire Underwriters as Mechanical Engineer. Until recently he was associated with the Stroudsburg Engine Works, as Superintendent and Mechanical Engineer.

Mr. Lawford H. Fry has contributed an article on The Advantages of the Use of Moderately Superheated Steam in Locomotive Practice, to the March 5 number of *The Railroad Age Gazette*.

Mr. Hugo Fuchs has severed his connection with the New York Central and Hudson River R. R. Co., and is now engaged as Consulting Engineer in Budapest, Hungary.

The fourth edition of Mr. William P. Gerhard's book, Guide to Sanitary Inspection, has been issued, entirely revised and enlarged.

Mr. W. W. Gore, formerly with the Fairbanks Morse Mfg. Co., Beloit, Wis., in the capacity of Experimental Engineer, has become Vice-President of the Gas Power Manufacturing Co., with office in Seattle, Washington.

Comparative Tests of Run-of-Mine and Briquetted Coal on Locomotives, by Prof. W. F. M. Goss, extracts from Bulletin 363 of the United States Geological Survey, was published in the February issue of *The American Engineer and Railroad Journal*.

An abstract of Mr. J. C. Wm. Greth's paper, Impurities Causing Scale and Corrosion, which he read before the American Institute of Chemical Engineers, appeared in the March 2 number of *Power and the Engineer*.

Mr. George T. Gwilliam has become Resident Manager of The Hess-Bright Mfg. Co., 1974 Broadway, New York.

The March 18 issue of *The Automobile* contains an article, Automobile Cooling Systems Analyzed, by Mr. Morris A. Hall.

Mr. Adalbert Harding, formerly employed by the Westinghouse Machine Co., is now representing the Wickes Boiler Co., in the eastern territory, with an office in the West Street Bldg., New York.

Mr. Louis G. Henes, formerly Manager of the machine tool department of Harron, Rickard & McCone, has opened offices in the Monadnock Building, San

Francisco, Cal. He will carry on a railway, industrial and contractors' equipment business.

Mr. Herbert T. Herr, formerly of Denver, Colo., has accepted a position as General Manager of the Westinghouse Machine Co., East Pittsburg, Pa.

Mr. Reuben Hill, until recently associated with Tiffany Studios Factory, Corona, L. I., N. Y., has become Factory Manager of The Bristol Engineering Corporation, Bristol, Conn.

Mr. Arthur H. Hutchinson has accepted a position with the C. W. Keltning Mercantile Co., Denver, Colo.

Prof. F. R. Hutton delivered a lecture on Large Gas Engines at a meeting of the Mechanical Engineering Society of Columbia University, February 18.

Mr. R. B. Jackson, formerly Factory Manager of the Olds Motor Works, and more recently General Manager of the E. R. Thomas Motor Co., Buffalo, N. Y., is now General Manager and Treasurer of the Hudson Motor Car Co. of Detroit.

Mr. Washington Jones has been elected an honorary member of the Engineers' Club of Philadelphia, of which he has long been an active member.

Mr. Robert Thurston Kent has resigned as Engineering Editor of the Iron Trade Review, Cleveland, O., to become Managing Editor of *Industrial Engineering*, Pittsburg, Pa., a new paper devoted to mechanical engineering subjects. Mr. Kent has been with *The Iron Trade Review* since 1905, and prior to that time was Associate Editor of *The Electrical Review*, New York.

In the March 2 number of *Power and the Engineer* was published an article on Removal of Oil and Grease from Boiler Feed Water, by Mr. Arthur E. Krause.

Mr. R. K. LeBlond sailed, Feb. 11, for an extended trip to the Mediterranean.

Mr. John E. Lord has accepted a position with the Sight Feed Oil Pump Co. in the capacity of Assistant Manager.

Mr. William H. McKiever, recently associated with the Wells & Newton Co., New York, has opened an office at the Everett Bldg., and will conduct a general engineering and contracting business.

The February issue of *Cassier's Magazine* contains a biographical sketch by William L. Cathcart, Charles H. Manning, Chief Engineer, U. S. N., Retired.

Mr. Harry J. Marks, formerly with the Empire State Engineering Co., is now associated with Mr. Edward P. Hampson, 170 Broadway, in a general engineering business.

An illustrated article on Dynamometer Car of the University of Illinois and the Illinois Central Railroad, by Mr. F. W. Marquis, appeared in the February 19 issue of the *Railroad Age Gazette*.

Mr. Daniel W. Mead is the author of a book on Water Power Engineering.

Col. E. D. Meier, an authority on smoke abatement, addressed the Milwaukee Public City Club on the evening of February 3.

Mr. Arthur E. Michel has opened an office in the Hudson Terminal Building, 50 Church St., New York, as Advertising Engineer. He was recently Manager of the George H. Gibson Co., New York.

Mr. Fred J. Miller, Vice-President of the Society, became connected March 1, with the Union Typewriter Co., New York, as Assistant to the President.

Mr. Harvey E. Molé and Mr. Charles O. Lenz have opened offices at 71 Broadway, New York, under the firm name of Lenz & Molé, and will carry on a general engineering business.

Mr. Stanley H. Moore has issued a book called Mechanical Engineering and Machine Shop Practice.

Mr. E. R. Morrison has published a book called, Morrison's Spring Tables.

Mr. A. F. Murray has accepted a position with the Geo. F. Blake Mfg. Co., East Cambridge, Mass. He was until recently connected with Elliott-Fisher Co., Harrisburg, Pa.

Mr. Geo. R. Murray has been appointed President of The Maxwell Rolf Stone Co., Cleveland, O. He was formerly connected with the Ingersoll-Rand Co., New York, as General Manager of Sales.

Mr. F. H. Neely, until recently in the employ of the Westinghouse Electric and Manufacturing Co., has opened offices for industrial engineering, in Atlanta, Ga.

Prof. R. B. Owens has retired on account of ill-health from McGill University, where he was Professor of Electrical Engineering.

Mr. Cortlandt E. Palmer has tendered his resignation as vice-president, director and consulting engineer of the Esperanza Mining Co. to take effect on April 1, terminating six years of continuous connection with the property in charge of operations.

An article by Mr. E. N. Percy on Large Gas Engines for Ships was published in the January 30 issue of *Scientific American Supplement.*

Mr. George W. Rink has succeeded Mr. B. P. Flory as Mechanical Engineer of the New Jersey Central Railroad. Mr. Rink was formerly Chief Draftsman M. P. Dept., of this railroad.

Mr. William F. Rust, who was until recently connected with the American Sheet and Tin Plate Co., Pittsburg, Pa., as Assistant Engineer, has accepted a position with the Youngstown Sheet and Tube Co., Youngstown, O.

Mr. James E. Sague has been nominated by Governor Hughes, Public Service Commissioner in the Second District, to succeed himself, for a term of five years.

Mr. William L. Saunders, President of the Ingersoll-Rand Co., has been appointed a member of a special committee of the Chamber of Commerce of the State of New York to prepare a report on the Panama Canal. The Committee will probably review the findings of several engineers on the question of the merits of a sea level canal as against a lock canal, and investigate the advantages of the canal to American commerce, and will likely report on the question of the benefits to be derived from the canal in the future.

Mr. William E. Smith has resigned his position with the American Locomotive Co., and accepted a position in the Mechanical Engineering Department of the Lackawanna Railroad, Scranton, Pa.

Mr. W. B. Snow is the author of The New Power Plant of the Somerset Coal Co., published in the March 1 number of *The Practical Engineer.* Mr. Snow has recently been elected a member of the corporation of the Massachusetts Institute of Technology.

Mr. O. C. Spurling has become Plant Engineer of the Western Electric Company, Hawthorne, Ill. He was formerly Assistant Plant Engineer, also Factory Engineer, of the same company.

Dr. Charles P. Steinmetz is the author of General Lectures on Electrical Engineering.

Mr. Chas. A. Straw has become Mechanical Superintendent of The Lehigh Coal and Navigation Co., Lansford, Pa. He was formerly associated with the Lehigh Valley Coal Co., Wilkes-Barre, Pa., as Mechanical Engineer.

Mr. Robert Barnard Talcott was appointed by executive order, Assistant Chief Mechanical and Electrical Engineer, office of Supervising Architect, Treasury Department, Washington, D. C. He was until recently General Manager of the Vacuum Cleaner Co., New York.

Dr. Fred. W. Taylor gave an address before the College of Engineering of the University of Illinois, Thursday, February 18, along general engineering lines supplemented by anecdotes from the early part of the careers of successful engineers. On February 16, Dr. Taylor was entertained by a group of local manufacturers in Cincinnati, O. During the evening he gave an address on technical subjects.

Mr. Henry R. Towne, President of the Yale & Towne Mfg. Co., was unanimously reëlected President of the Merchants' Association of New York, February 25, 1909.

Mr. A. F. Van Deinse, who was Sales Manager, Chas. C. Moore & Co., Los Angeles, Cal., is now associated with the El Tiro Copper Co., El Tiro, Pima Co., Arizona.

The Hammer Blow from Incorrect Counterbalance, by Mr. H. H. Vaughan, appeared in the February issue of the *American Engineer and Railroad Journal.*

The Board of Water Supply of New York has announced the appointment of Mr. Arthur West as Expert Mechanical Engineer.

The March 9 issue of *Power and the Engineer* contains Safety Valves, by Mr. Frederic M. Whyte, together with some of the discussion presented at the February 23 meeting of the Society.

Mr. H. V. Wille's paper on A New Departure in Flexible Staybolts appeared in the February 13 issue of *The Railway and Engineering Review.*

MEMORIAL

GUSTAVE CANET

Honorary Member, Am. Soc. M. E.

Gustave Canet was born at Belfort, France, on September 29, 1846. He was educated at the University of Strasburg and the École Centrale des Arts et Manufactures, at Paris. He first gave attention to railway construction, and was attached to the railway works at Reichshoffen, Alsace. In August 1870, the Franco-German war having broken out, he was gazetted Lieutenant of Artillery in the Gardes Mobiles du Haut-Rhin and ordered to Neuf-Brisach with his regiment. He was present at the siege of that town, and took an active part in the construction of its lines of defense, being afterwards made a prisoner of war by the Prussian Army and sent to Leipzig. At the close of the war, and after his liberation, he resumed railway engineering work and found active employment in the construction of the Delle-Porrentruy Railway, Switzerland.

All matters relating to artillery and fortifications had always evoked in him the keenest interest, and in 1872 he severed his connection with the Swiss railway above referred to, and took an appointment with the London Ordnance Works Company, the property of M. Vavasseur, the eminent British specialist in gun construction, who at that time was established in Southwark. As early as 1876 M. Canet propounded the theory of hydraulic brakes for checking the recoil of guns, and put forward new principles for the construction of gun carriages and mountings, thus originating a new era in the manufacture of ordnance.

He left this company in 1881 and put in an ordnance department at the works of the Société Anonyme des Forges et Chantiers de la Méditerranée, at Havre, where he remained until 1897. During that period the ordnance department of the French company in question built the armament for the foreign men-of-war designed and constructed at the shipyards of the firm located on the Mediterranean and on the Atlantic. Progress in this respect was marked, especially following upon the bill passed in the French Parliament in 1885, authorizing the free manufacture in France of war material destined

for foreign governments. This led to an extension of the Havre Ordnance Works, and the construction of all types of guns, in addition to naval ordnance, was gradually taken in hand.

In 1897 the Schneider Works at Creusot was amalgamated with the Havre Works, and from 1897 to 1907 the whole was placed under the directorship of M. Canet. Vast sums were expended in developing ordnance factories and proving-grounds at both places, and a long-range proving ground was added at Tancarville.

M. Canet retired from active business at the commencement of 1907, but remained the technical adviser of the Schneider Company in matters concerning armament. At the time of his death, therefore, he had served French industry for a period of over twenty-six years.

It will be remembered that after the disastrous explosion on board the French battleship Jena, the expert knowledge of M. Canet was again called into requisition by the French Government, and he was appointed a member of a committee formed to investigate the whole question of explosives.

M. Canet was Past-President of the Société des Ingenieurs Civils de France, of the Association Amicale des Anciens Elèves de l'École Centrale, and of the Association Française pour la Protection de la Propriété Industrielle, of which he was elected Honorary President. He was, further, Honorary President of the Chambre Syndicale des Fabricants et Constructeurs de Matèriel de Guerre; Honorary Member of the Imperial Technical Society of Russia; of the Iron and Steel Institute; President of the Junior Institution of Engineers; Member of the Institution of Civil Engineers and of the Institution of Naval Architects, England; Life Member of the Imperial Institute, England; of the Naval Institute of the United States of America; and of the French Société d'Encouragement pour l'Industrie Nationale; and Life Member, Member, or Founder, of numerous other French societies and institutions. He was also Commander of the Legion of Honor, and Officier de l'Académie, and held besides fifteen high decorations from foreign countries for services rendered them in regard to their rearmament.

M. Canet died October 7, 1908, at his seaside home, St. Aubin sur Mer, in Calvados, where since his retirement from active business he had spent a great part of his time.

HISTORY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Preliminary Report of the Committee on Society History

Chapter IX

GROWING INFLUENCE OF THE SOCIETY

217 In looking back over the development of The American Society of Mechanical Engineers from the first small beginning in the third floor room at the corner of Fulton and William streets to a strong and powerful organization, owning its own house in the center of New York City, and forming one of the central features at an international congress at the World's Fair, we realize the extent to which the Society is indebted to the efforts of a number of devoted men.

218 It has been said that it is only within recent years the engineer has taken his place as a business man as well as the creator of structures of stone, wood, iron, and steel, and as the manufacturer of power; but it is none the less true that in the years from 1881 to 1893, administrative qualities of a high order were shown in the development of the Society.

219 In its modest beginning, the headquarters of the Society was the office of the Secretary, a room of sufficient size for the small amount of business to be transacted, and for the meetings of the Council, this office being at the corner of Broadway and Park Place, in a building still standing (1909), although materially altered.

220 Upon the election of Prof. F. R. Hutton as Secretary in 1883

Under the direction of the Council the Committee on Society History has arranged to present the results of its investigations to the members of the Society. The Preliminary Report will appear in The Journal of the Society from month to month, and thus enable the matter to be open to comment during its completion. It is especially desired that any member who may be in the possession of facts or information bearing upon the various points as they are thus made public will communicate with the committee, in order that the final and completed report may have the advantage of the collaboration of the membership at large.

the office was removed to No. 15 Cortlandt St., near Broadway; and in 1885 it was again moved to No. 280 Broadway, in the building originally constructed by the late A. T. Stewart as his downtown store, and later converted into a business building.

221 It was in this latter location that the first plans for the formation of a library were consummated; and the request for contributions of books, trade catalogues and periodicals resulted in the filling of a bookcase, which, with the successors soon demanded, was the origin of the fine collection of books now forming a portion of the great engineering library which crowns the building in Thirty-ninth Street.

222 During those early days the question of the finances of the Society often formed the subject of earnest thought and discussion, and although the budget which then had to be met would look small in comparison with that of the present, it was more than once a weighty question for officers, committee and members. A glance over the early volumes of the Transactions will show the extent of the burden which the young organization had assumed.

223 With the growth in membership the number and extent of papers increased, and in a few years the size of the yearly volume fully equalled that issued by older organizations.

224 The names there met most frequently include some no longer living, and the work of Holley, Thurston, Wood, Hoadley, Worthington, Holloway, Babcock, and others remains to show the extent to which those devoted men gave time, effort and means to the organization.

225 It must be remembered that the period from the foundation of the Society to the World's Fair of 1893 was one in which many radical transformations in the work of the mechanical engineer were occurring. The general introduction of steel in the place of iron both for machine and building construction took place within that decade. The high-speed engine was developed to meet the demands of the electrical industry. The electrical industry itself was created in the course of those eventful years. Visitors to the Electrical Exhibition held in Philadelphia in 1884 will remember the Edison "Jumbo" dynamo as one of the wonders of the show, while those who saw it again, perched in the Electrical Building of the World's Fair at Chicago looked at it as a relic of a past age, as one gazes at the fragments of Stephenson's "Rocket" in the South Kensington Museum.

226 Practically the entire development of automatic machine-

tools occurred between the same limits of time, and indeed the transformation in machine tools generally which preceded the introduction of modern rapid cutting steels was the result of the efforts of men who were working also in and for the Society. Not alone in the electrical industry but in almost every other department of engineering work the enormous progress appearing between the mechanical exhibits at Philadelphia in 1876 and Chicago in 1893 was due in large degree to the genius and hard work of the members of the Society.

227 In the development of engineering education also the Society bore an important part and with that phase of engineering work it was identified from the start. From the organization meeting in the hall of the Stevens Institute in Hoboken, aided by the efforts of Professor Thurston and of Dr. Henry Morton, the Society has been an effective element in the progress of engineering education.

228 The ranks of the Junior membership were continually supplied from the graduates of the technical schools, while professors of engineering were included among its active contributors to the Transactions and on the floor at its conventions. To this firm bond of union between the teachers and the manufacturing engineers it is doubtless due that the old-time aloofness of the "practical" for the "theoretical" man has so largely been overcome, and it is due in no small degree to the meeting of professor, manufacturer, and student in the common ground of Society fellowship that science and practice have become so closely united.

229 The European trip of 1889 brought many of the members of the Society into close communication with the engineering work of the old world, and even those who had already had the opportunity of examining the workshops and methods of Great Britain and the Continent, found that the unparalleled opportunities afforded during that eventful trip far exceeded anything that could have been acquired by private individuals. The fellowship thus created between the Society and the various European organizations did much to broaden the work of the American association, placing it well in the front as a National society, representing a field of engineering work which had hitherto been relegated to a subordinate position. It is not too much to say that the prominence acquired by the Society in connection with the engineering features of the expositions of 1889 and 1893 gave it a strength and a status which have characterized its movements ever since.

230 Following upon the International Engineering Congress of

the Chicago Exposition came a development of interest in the work of the Society which caused an increase both in its membership and in the character and number of papers and discussions included in its Transactions, a development which will be given a general review in the present chapter, before proceeding with the detailed record of its work.

(To be continued.)

A METHOD OF IMPROVING THE EFFICIENCY OF GAS ENGINES

By Thos. E. Butterfield,[1] Philadelphia, Pa.

Non-Member

The movement toward higher efficiency among gas engine men has been in the direction of lengthening the high end of the indicator card, and securing greater range of expansion by reducing the clearance volume and increasing the compression. Due to the inevitable loss of heat when gases at high temperatures pass through ports and valves, the compound engine has failed to show any gain.

2 The old slide valve could not be used with high pressures, and the replacement of the slide valve by the poppet valve was followed by an increase in compression until a new limitation was reached. The speed of combustion became excessively great, resulting in shocks and loud poundings. Premature ignition or self ignition of the mixture of gas and air was encountered. These troubles caused the practical compression limit to be at four or five atmospheres.

3 With liquid hydrocarbons these troubles were most acute, and Diesel, while searching for the isothermal combustion engine, came upon the principle of controlled combustion and separate compression of gas and air. This cycle makes possible compressions of forty atmospheres but leaves a large part of the intermediate range still unused, because oil injected at the end of the compression will not promptly become gas and burn with much lower compression.

4 Banki cooled the charge and also the surface of the combustion chamber in the Otto cycle engine by introducing water vapor with the vapor of liquid fuel, and he used as high as fifteen atmospheres of compression. Water injection had been used before but not systematically. Banki's engine never attained commercial success. The destructive shocks resulting from accidental interferences with the water supply and the undue corrosion of the valves and the interior

[1] Chief Engineer Otto Gas Engine Works, Philadelphia, Pa.

To be presented at the Spring Meeting (May) 1909 of The American Society of Mechanical Engineers. All papers are subject to revision.

of the cylinder due to imperfect vaporization of the water were probably the principal causes that prevented extensive use of this engine.

5 Diluting the gaseous mixture with air has been suggested and tried out lately by Mr. Dugald Clerk. The discussion of this proposal recalls an idea first thought of about 20 years ago by Mr. John Saltar, Jr., late president of the Otto Gas Engine Works, and at that time their Chicago agent. It concerned a method of using high compression in the Otto cycle engine by diluting with an inert gas the combustible charge drawn in during the suction stroke. A patent application was drawn up but never submitted; and the following extracts from this application show clearly the essential features in the words of the inventor.

My invention relates to engines wherein individual charges of fluid fuel and air are successively mixed and ignited. It is well known that the efficiency of combustion in engines of this class is increased with the degree of compression at which the charge is ignited. However, such preliminary compression is subject to practical limitation in that a great increase thereof beyond such limitation yields an indicator card showing relatively too great initial pressure and high temperature of combustion, and is accompanied by undue shocks upon the engine, manifested by noisy poundings.

I have ascertained by practical tests that with a fuel which is poorer than gasoline vapor a higher degree of compression may be employed without the disadvantages above specified. So that a relatively poor gas has a higher power-producing value, in an engine of this class, than what may be considered its heating equivalent in a richer gas. For instance, I find that a volume of 4 cu. ft. of ordinary "producer gas," containing 130 B.t.u. per cu. ft. equals in the amount of horse power generated under its proper compression and combustion, a volume of 1 cu. ft. of ordinary "City" gas, containing 650 B.t.u. per cu. ft., or 520 B.t.u. in producer gas, yields as much power as 650 B.t.u. in City gas. Moreover, I find that if a charge of gasoline vapor and air be modified by the addition and proper admixture therewith of a percentage of inert fixed gas (i.e., one which neither burns nor supports combustion), the charge can be subjected to a higher preliminary compression than would be practical for that particular fuel in its undiluted condition; the initial pressure of the combustion being reduced without a proportionate reduction of the mean effective pressure; and a large saving is effected in the total quantity of gasoline required to produce a given result in horse power.

I have found in practice, that the waste inert products of previous combustion, by proper treatment, may be economically utilized in diluting the charge of rich fuel, and, as I find it desirable to eliminate the moisture of combustion and also to reduce the temperature of the products of combustion, for this purpose, the embodiment of my invention selected for illustration comprises apparatus to accomplish such result.

I have operated such an engine with charges thus diluted; igniting them at a pressure of 120 lb. per sq. in., and, without disadvantageous poundings or exces-

sive initial pressure and temperatures, the noise of combustion being practically no greater than that incident to the ignition of the undiluted mixture of gasoline vapor and air at a pressure of 60 lb. per sq. in. The result of such operation was the saving of 25 per cent of the gasoline, in producing a given horse power.

Although I find it convenient so to arrange my improved engine that its supply of diluting material is obtained from its own exhaust, it is to be understood that any fixed gas which is capable of thorough admixture with the charge of fuel and air without imparting undesirable qualities thereto, and which is so substantially inert in comparison with the fuel itself as to diminish the heat value thereof per unit of charge, may be employed for the purpose described.

6 Experiments designed to show the practical working effect of this method were made in Chicago, prior to 1898, and at The Otto Gas Engine Works, Philadelphia, 1899–1902.

7 The first experiments at Philadelphia were made in October and November 1899. A 20 h.p. Otto gasolene engine, with cut-out governor and automatic air valve, was used. Its bore was $8\frac{1}{2}$ in.; stroke 15 in.; revolutions 240 per minute; stroke volume $851\frac{2}{10}$ cu. in.; compression space $26\frac{36}{100}$ per cent of the stroke volume.

8 The dilution of the charge with exhaust gas was first effected by lengthening the exhaust cam, thus holding the exhaust valve open during a portion of the suction stroke and drawing in exhaust gas from the exhaust pipe while the gasolene vapor and air were drawn in through the inlet valve. Tests were made successively with the exhaust valve closing at 86 deg., 73 deg., 60 deg., 41 deg., and 25 deg., after the beginning of the suction stroke. The best results were obtained with the exhaust valve opening at 127 deg. after the beginning of the explosion stroke, and closing at 25 deg. after the beginning of the suction stroke. With a compression pressure of 80 lb. per sq. in. a fuel consumption of $\frac{8}{10}$ pints of gasolene per brake horse-power hour was obtained with quiet running. The maximum brake horse-power however, was reduced from 21 to 19.

9 With the exhaust valve closing early and thus retaining a larger than normal proportion of exhaust gas in the cylinder, the efficiency was reduced and the explosions were much more violent. This was no doubt due to retention of an excessive amount of heat in the cylinder.

10 To insure a cool charge and a uniform supply of burnt gas, in another experiment, the exhaust of a smaller engine was led through two exhaust vessels and then carried to the air inlet holes in the frame of the engine. This gave a better efficiency, a fuel consumption of 0.75 pints per brake horse-power per hour being obtained with smooth running.

11 This compression was very moderate and not thoroughly adapted to test the influence of burnt gas dilution in making the running quiet.

12 In order to separate the gasolene and air further and thus reduce the suddenness of the explosion, burnt gas instead of air was used to vaporize the oil, but the effect of the change in method was but slight.

13 Another series of experiments was made in February and March 1902 with a 15 h.p. Otto gasoline engine with $6\frac{3}{4}$ in. bore, $15\frac{1}{2}$ in. stroke and 260 r.p.m. The compression space was 17 per cent of the stroke volume. The burnt gas inlet was controlled by a timed poppet valve. Several experiments were made with short connections between the exhaust and inlet, but the best results were obtained with a long pipe connection containing about 9 stroke-volumes of burnt gas. The maximum brake horse-power was about 14, and the gasolene consumption per brake horse power per hour in pints 0.692, 0.701, 0.710, 0.691, 0.702, 0.697, 0.691, 0.69. The pounding was a little louder than with the low compression engine, but could be kept within permissible limits.

14 An attempt to follow the action of inert gas dilution by means of figures was made at the time of the later experiments. As a basis for calculating the results given in the table, it was necessary to make certain assumptions which cannot be verified. Nevertheless, any error in any of these figures will not affect the usefulness of the comparison drawn from the table.

15 The temperature of the burnt gas in the clearance at the beginning of the suction stroke is assumed at 1200 deg. fahr., absolute. This is, of course, much lower than the temperature at the beginning of the exhaust stroke.

16 The temperature of the mixture as it enters the cylinder is taken at 530 deg. fahr., absolute. This varies of course, with different liquid fuels, according to the vapor tension and the latent heat of vaporization; for instance, grain alcohol with a latent heat of 371 B.t.u. per pound, will, if perfectly vaporized, lower the temperature of the explosive mixture 148 deg. fahr., and wood alcohol with a latent heat of 481 B.t.u. per lb. will cause a drop of 258 deg. fahr. Such fuels with high latent heat of vaporization are only partially evaporated, and there is probably a considerable proportion of such fuels present in the liquid form at the time of ignition, either as a mist or as condensation on the cooler parts of the walls of the combustion chamber. The tremendous absorption of heat by a liquid

so diffused through the charge at the time of inflammation probably has an important influence in reducing the speed of combustion and thus making possible high compression with these fuels.

17 Atmospheric pressure is taken at 15 lb. and the pressure in the cylinder at the end of the suction stroke is taken at 14 lb. per sq. in. absolute.

18 The proportion of burnt gas in the entering charge is P, and the percentage will be 100 P. The ratio of clearance to stroke-volume is C. The temperature of mixed gases in the cylinder at the end of the suction stroke is T_1. The specific heat of the charge before and after burning is taken the same; 0.17 at constant volume and 0.22 at constant pressure, with the ratio 1.3.

19 With a cylinder stroke-volume of one cubic foot, the burnt gas left in the cylinder at the end of the suction stroke expands to $\frac{15}{14}$ C, the exhaust stroke being finished at atmospheric pressure.

20 Assuming no passage of heat to the cylinder walls, the heat lost by this burnt gas left in the clearance in mixing is the same as the heat gained by the entering charge. And as the thermal capacities of equal volumes of permanent gases reduced to the same pressure and temperature are always the same, the equation follows:

$$\frac{15}{14}C \times \frac{492}{1200}(1200 - T_1) = \left(1 + C - \frac{15}{14}C\right) \times \frac{492}{530}(T_1 - 530)$$

$$T_1 = \frac{1 + C}{\left(1 + C - \frac{15}{14}C\right)\frac{1}{530} + \frac{15\,C}{14 \times 1200}} = \frac{530\,(1 + C)}{1 + \frac{4}{10}C} \text{ Approx.}$$

The compression pressure is given by the formula

$$P = 14\left(\frac{(1 + C)}{C}\right)^r$$

The temperature of compression is

$$T^2 = T\left(\frac{1 + C}{C}\right)^{r-1} = \left(\frac{1 + C}{C}\right)^{\frac{3}{10}}$$

21 The number of B.t.u. released by combustion is taken at 52¼ for each cubic foot of the perfect combustible mixture of fuel and air. This low value gives figures for the explosion pressure somewhere near the actual, without introducing any figures in regard to suppressed combustion or possible variation of specific heat. The num-

ber of B.t.u. per cu. ft. stroke-volume of the mixture actually present in the cylinder at the end of the suction stroke is

$$52\tfrac{1}{4} \times \frac{492}{530}(1 - P) \times \frac{14 - C}{15} = 3.234\ (1 - P)\ (14 - C)$$

The number of B.t.u. per cubic foot of clearance volume is

$$3.234\ \frac{(1 - P)\ (14 - C)}{C}$$

22 The approximate composition of burnt gas when freed from water is taken at about 18½ per cent carbonic acid gas, 2½ per cent of unburnt excess oxygen, and 79 per cent of nitrogen. A cubic foot of this mixture will weigh about 0.0868 lb. at 32 deg. fahr. A cubic foot of air weighs about 0.0808 lb. and when carburetted with heavy gasolene vapor will weigh about 0.0837 lb. per cubic foot.

23 Adding the weight of burnt gas left in the clearance, which is equal to

$$0.0868\ C\ \frac{492}{1200} = 0.03559\ C$$

to the weight of mixture drawn in during the suction stroke, which is

$$0.0837 \cdot \frac{14 - C}{15} \cdot \frac{492}{530}$$

the total weight of charge in the cylinder at the end of compression is, approximately, 0.0725 + 0.0304 C and the thermal capacity of this charge is 0.17 (0.0725 + 0.0304 C) = 0.01233 + 0.0052 C.

24 The rise in temperature of the charge on complete combustion is

$$\frac{3.234\ (1 - P)\ (1 - C)}{0.01233 - 0.0052\ C}$$

25 The thermal efficiency is

$$E = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{C}{1 + C}\right)^{\frac{3}{10}}$$

and the mean effective pressure is

$$\frac{778\ \mathrm{E} \times \text{B.t.u. per cu. ft.}}{144}$$

Stroke-volume = 0.54 EH.

26 The figures for a moderate compression of 30 per cent of stroke volume and a very high compression of 15 per cent of the stroke volume, are given below for easy reference:

Clearance per cent	% Rise	30	15
Compression temperature	11	952	1060
Compression pressure	111	94	198
Rise in temperature at explosion	7	3188	3410
Explosion temperature	8	4140	4470
Explosion pressure	104	409	834
Mean effective pressure	29	85	110
Thermal efficiency	29	35.6	45.7
Ratio weight explosive mixture to weight burnt gas	103	6.55	13.28

27 This shows the rise in explosion temperature to be only 8 per cent, which is inconsiderable, but both compression and explosion pressures rise very rapidly, and the dilution of the charge by burnt gases left in the clearance space is reduced more than 50 per cent.

28 The actual pressure and temperatures in the cylinder at the end of compression can have no important influence on the character of the explosion, for with 30 per cent clearance it is necessary only to burn a little more than 3 per cent of the charge before the temperature in the cylinder is higher than that at the end of compression with 15 per cent clearance; and, similarly, it is necessary only to burn one-third of the charge with 30 per cent clearance before the pressure in the cylinder rises to the same figure as at end of compression with 15 per cent clearance. The remaining portion of the charge is not burnt at an increasing rate of speed, but rather at a decreasing rate, even in the presence of these high pressures and temperatures.

29 To explain the difference in behavior of the highly compressed charge, we are accordingly compelled to neglect compression temperatures and pressures, leaving for consideration the difference in density of the compressed charges as expressed in heat units per cubic foot and in pounds per cubic foot.

30 With the higher compression, the particles or molecules of gas and oxygen are shoved closer together, the intermolecular distances with 30 per cent and 15 per cent clearance roughly comparing as the cube root of two to one. As combustion at constant volume proceeds, particles or molecules of carbonic acid are being constantly interposed between the active molecules of gas and oxygen. It is true that the condensible hydrocarbons probably do not burn directly to carbonic acid, but may pass through one or more intermediate stages, but the action even in this case is similar, in

that the most active elements become further separated from the instant when combustion starts.

31 The speed of combustion which we know to obtain in gaseous mixtures is probably increased by these intervening particles of more or less inert gas acting as carriers The process may be said to begin with the gas and oxygen molecules adjacent everywhere throughout the charge, except for the separation by nitrogen. As the combustion proceeds the particles of CO_2,CO, the aldehyds, etc., are pushed in between, making the path of transfer between the active particles longer every instant.

32 When the process of combustion has gone far enough to place a certain critical amount of inactive gas between the particles of active gas, the speed of burning rapidly falls off, and this assumed phenomenon furnishes a rational explanation of the much discussed "suppressed combustion." This occurs even with such gases as CO and H, where the formation of an intermediate compound is practically barred, and it also always occurs in the face of the approach to maximum pressures and temperatures.

33 Since suppressed combustion of gaseous mixtures is present where low compression and explosion pressures and temperatures exist, and also where high compression and explosion pressures and temperatures exist, this action must be dependent on some relation or cause not dependent on the variations induced by change in clearance, such as in pressures, temperatures and densities.

34 The gradual dilution of the charge by the more or less inert products of its own complete or partial combustion is, however, always a feature of such combustion, and may reasonably be supposed to be the determining factor in fixing the character of this action.

35 If this automatic dilution has such a marked influence on the nature of every combustion or "explosion" that takes place in the cylinder of a gas engine, it is beyond doubt that the artificial creation of such conditions will also result in the production of corresponding effects. In other words, dilution of the charge with burnt gas, or perhaps with other inert gas, will result in the creation of suppressed combustion at the beginning of combustion, instead of as in the undiluted charge, waiting until combustion is partially complete. By varying the amount of such initial dilution, also, the character of the combustion may be controlled within wide limits.

36 Especially in small engines, a practical difficulty presents itself in the increasing difficulty of securing positive ignition as the quality of the charge is altered by dilution.

37 With a strong electric spark, ignition is more prompt and certain wth high compression and consequently poorer charges may be certainly ignited; but the dilution of the charge necessary to secure slow combustion with high compression is probably so great that certain ignition cannot be relied upon under all conditions. In larger engines the difficulty is not likely to be so serious, and by using a small portion of the total charge without any dilution, the ignition may always be made certain.

38 By advancing the time at which suppressed combustion becomes evident, and lengthening its extent, the dilution of the charge with inert gas causes a diminution of the maximum temperature range with any compression, and thus involves a loss in efficiency. But with a practical and reasonable amount of dilution, or just enough to make the use of a high compression possible, this loss is bound to be inconsiderable compared to the gain resulting from the use of the higher compression.

39 The chief drawbacks to the use of high compression with dilution are the loss in mean effective pressure, and the danger of destructive shocks should undiluted charges be accidentally drawn into the cylinder and compressed and ignited.

40 In the tests made at the shops of The Otto Gas Engine Works no meters were used to determine the exact proportions of the various constituents of the mixture drawn into the cylinder. The percentage of burnt gas used was estimated from the loss in mean effective pressure, a method open to serious objection. The effort was made to separate out all the water of condensation in the burnt gas created by the combustion of hydrogen, but no hygrometric tests were made to determine the exact quantity of water present. As the amount of aqueous vapor in a charge may have a quite appreciable effect on the character of the combustion, the absence of such a test was a drawback.

41 Refined measurements are seldom possible in ordinary commercial work, however, especially when exploring a new field; and it is to be hoped that the subject may be exhaustively investigated in some of our college laboratories.

TABLE 1 THERMAL DATA FOR NO DILUTION OF CHARGE

ABSOLUTE TEMPERATURES AND PRESSURES

Clearance in per cent of Stroke Volume	35	32	30	27	25	22	20	17	15	12	10
Temperature at End of Suction	628	620	613	608	604	594	588	582	575	566	561
Pressure of Compression	81	88	94	100	113	130	144	172	198	255	316
Temperature of Compression	941	948	952	967	979	993	1006	1039	1060	1106	1152
B.t.u. per cu. ft. Stroke-volume	44.1	44.2	44.3	44.4	44.4	44.5	44.6	44.2	44.7	44.8	44.9
B.t.u. per cu. ft. of Clearance	126	134	147	164	178	212	223	263	298	373	449
Maximum Temperature	4060	4110	4140	4200	4235	4290	4310	4420	4470	4550	4640
Maximum Pressure	349	381	409	434	488	552	616	732	834	1050	1255
Thermal Efficiency	33.2	34.6	35.6	37.1	38.3	40.2	41.6	44.0	45.7	48.8	51.3
Mean Effective Pressure	79.0	82.4	85.0	89.0	91.5	96.5	100	106	110	118	124
Total Weight of Gas per cu. ft. Stroke-volume	0.0831	0.0822	0.0816	0.0807	0.0801	0.0792	0.0786	0.0777	0.0771	0.0762	0.0756
Weight Burnt Gas per cu. ft. Stroke-vol.	0.0126	0.0115	0.0108	0.0097	0.0090	0.0079	0.0072	0.0061	0.0054	0.0043	0.0036
Ratio Weight of Explosive Mixture to Burnt Gas	5.59	6.13	6.55	7.32	7.90	9.03	9.91	11.75	13.28	16.70	20.00
Weight Explosive Mixture per cu. ft. Stroke-volume	0.0705	0.0707	0.0708	0.0710	0.0711	0.0713	0.0714	0.0716	0.0717	0.0719	0.0720

TABLE 2 EFFECT OF DILUTION OF CHARGE WITH INERT GAS

CLEARANCE 15 PER CENT OF STROKE-VOLUME

Per cent of Inert Gas in Entering Charge	None	10	15	20	25	30	35	40	45	50
Per Cent of Inert Gas in Total Volume	7.2	16.5	21.1	25.8	30.4	35.0	39.7	44.3	49.0	53.6
B.t.u. per cu. ft. of Stroke-Volume	44.7	40.2	38.0	35.8	33.5	31.3	29.1	26.8	24.6	22.3
B.t.u. per cu. ft. of Clearance	298	268	253	238	224	209	194	179	164	149
B.t.u. per Pound	580	520	491	461	431	402	372	343	314	285
Rise in Temperature at Explosion	3410	3055	2885	2708	2534	2363	2189	2019	1844	1674
Maximum Temperature	4470	4115	3945	3768	3594	3423	3249	3079	2904	2734
Maximum Pressure	834	768	737	703	671	640	608	576	543	511
Mean Effective Pressure	110	99	93	88	83	77	71	66	61	55

SAFETY VALVE MEETING

SAFETY VALVES

By Frederic M. Whyte, New York
Member of the Society

The general subject of safety valves is such a very broad one that it would be impossible to consider it fully in one paper and it will be my purpose merely to open the subject of safety valves for steam boilers for discussion. In general the engineering profession has been quite ignorant about the principles of safety valves, their relative capacities, and the capacities required for various conditions of steam generation; inasmuch, therefore, as these items have recently been given very extended and careful study, and many interesting data have been collected, this may be considered an appropriate time and place to make such information available. It is the purpose of this paper to present some ideas about safety valves for steam boilers and particularly for locomotive boilers.

2 Just how the capacity of the first valve used on a steam boiler was determined, or what relation this capacity had to the generating capacity of the boiler, may be recorded somewhere in history, but it is doubtful if either fact was recorded or even determined. So far as locomotive work is concerned, the same ignorance prevails today; it is well to remember, however, that there is good promise that this ignorance will soon be dispelled. In marine work certain formulae have been devised for calculating the sizes of safety valves, and these formulae have been accepted, more or less blindly, it is thought.

3 As the writer is more familiar with locomotive work than with other lines, it will be more consistent to confine these remarks to that branch of the subject, with the understanding, however, that those who discuss the subject may consider locomotive, marine and stationary boilers.

Presented at the monthly meeting (February 1909) of The American Society of Mechanical Engineers. All papers are subject to revision.

PRACTICE IN LOCOMOTIVE WORK

4 The general practice in locomotive work has been to determine in an "offhand" way the size and number of safety valves to be used, and former practice has guided the determination entirely. If a larger boiler is to be used the valve capacity may not be increased, depending upon the judgment of the person whose duty it is to determine the capacity. Again, the capacity has been indicated in an indifferent manner, being expressed as a "size," meaning the diameter of something more or less uncertain; while the other dimension, the lift, which is necessary to give an indication of the capacity, is entirely ignored.

5 But to know the exact capacity of the available valves is not sufficient; it is quite as important to know how much steam is to be released and in what length of time it should be released. It will be comparatively easy to determine the capacity of safety valves, if indeed the elaborate tests which have already been made—data from which it is hoped may be presented in the discussion—have not already solved part of the problem; more difficult will be that part of it which is concerned with the quantity of steam to be released and the rate of the release. The subject is of mutual interest to the valve manufacturer and the user, the design of the valve for capacity and wear to be worked out by the manufacturer, the capacity which is to be used, both in volume and in number of valves, and the rate of release, to be determined by the user with the assistance of the manufacturer.

ESSENTIALS OF A SAFETY VALVE ON A LOCOMOTIVE

6 The design of the valve will include the diameter of the controlling opening and the passages leading to it from the steam volume, as well as those leading from it to the atmosphere, the shape and material of the seat, the amount of lift of the valve, and the shape and material of the valve face, the spring and its protection, the adjustment, the muffler. if one is to be used, and the action of the valve in lifting and in seating.

7 It will not be necessary to discuss the diameter of the controlling opening, and of the passages to and from it, in view of the suggestion here made that instead of indicating the capacity of a valve in a very rough way by the diameter of some opening, the capacity be expressed in pounds of steam at certain pressures. The shape of the seat and of the valve face may or may not be of importance; but this

will be referred to again. The material in the seat and face will naturally be that which will best withstand the effects of the flow of steam over them, and the possible pound of the valve when seating.

8 The reliability of the spring and the effect of heat upon it are very important points. Adjustments should be readily made, but on the other hand to get out of adjustment should be practically impossible. The capacity of the muffler need not be questioned, except in extreme designs, but the indicated capacity should be that of the valve complete, with or without muffler, according to the intended use of the valve; then it is important only that it deaden sufficiently the noise of the escaping steam.

9 The action of the valve in lifting and in seating, the desirability of a forewarning that the maximum pressure is about reached, and the operating conditions which bear upon this question of forewarning, are correlative. With any kind of steam-generating plant it ought to be quite sufficient if those immediately responsible for the quantity produced, and for its use, know what is available; in stationary and in marine work this is generally true, and steam gages can be placed within view of those who should know what the pressure is at any time; unfortunately in locomotive work, however, it has become perhaps desirable that others than those within view of the gage in the cab know something about the steam pressure, and inasmuch as the fireman is willing, and sometimes anxious, that they should know, he takes the only means at hand to inform them when he thinks that the results of his labors are good, and "fires against the pop" so that everybody within hearing or sight of the valve knows by the escaping steam that the fireman is doing his duty. If when a train is ascending a grade the conductor at the rear sees steam escaping from the valve he knows the train will get up the grade; on hard grades he will watch for the only indication which can be given him, and the fireman tries to present this indicator, the escape from the valve, the "white feather."

10 Numerous similar examples might be mentioned, but assuming that such an indicator of steaming conditions has grown to be a necessity, undesirable as it may be, how can it be produced at the least expense? Surely not with a valve from $2\frac{1}{2}$ to 4 in. in diameter and open to its full capacity. Two devices, at least, are available, to give the indication at a lower cost than the full open valve: the "simmering" valve, which will open slightly for two or three pounds, about the normal maximum, and then open full, just reversing this in seating; the other, the small pilot valve, which will open at two or

three pounds pressure below the working valve. The first method will have some bearing on the kind of metal to be used in the valve seat and valve face and possibly upon the shape of the exterior edge of the valve and the opposing surface of the seat. The second method means the addition of the small valve, an additional cost for which there will be no need if the first method can be developed successfully.

RELATION OF VALVE CAPACITY TO STEAM-GENERATING CAPACITY

11 There remains for consideration the relation of valve capacity to steam-generating capacity, and the unit capacity of the valves which will make up the total valve capacity. The fact that in locomotive work the total valve capacity has not been as great as the maximum steam-generating capacity should be ample proof that such valve capacity is not necessary. The reason for this is, of course, that on account of using the exhaust steam for producing the forced draft, when the demand for steam from the boiler is reduced or entirely cut off, the forced draft is automatically reduced or cut off, and the generating capacity is reduced so that it is not necessary that the safety valves release the full generating capacity. Probably it will be largely a question of opinion what per cent of the total generating capacity the valve ought to have, although it is possible that as attention is centered upon this question some more or less positive solution of it may result.

12 Having fixed upon the per cent of the generating capacity to be provided for in the valves it will be necessary to determine the desirable unit capacity of the valves. Some states require that each locomotive boiler have at least two valves. Starting with this condition, consideration of the maintenance of the valves indicates that they should be duplicates and therefore that each have a capacity equal to one-half the required generating capacity. If a number of boilers of different capacities are to be considered, then the smaller ones would probably be provided with the same valves as the larger ones for the purpose of duplication. There are some large boilers for which three valves might be necessary, because the necessary capacity in two units might make the valves abnormally large for construction purposes. Also it is worth while to consider whether undesirable results would come about from opening almost instantaneously an escape of steam from the boiler to the atmosphere. No suggestions are offered on this, but it is hoped that something bearing on the question may be developed in the discussion.

13 It is suggested that instead of setting the several valves on a boiler at different pressures, all the valves be set at the same pressure, with the idea that each of them will operate frequently enough to keep all in working condition, rather than run the risk of one valve being found out of condition when it is required for action.

14 It is probable that some time it will be found desirable to consider the minimum distance above the steam releasing surface of the water at which the safety valve seat may be placed.

SAFETY VALVE CAPACITY

By Philip G. Darling, New York

Associate Member of the Society

The function of a safety valve is to prevent the pressure in the boiler to which it is applied from rising above a definite point, to do this automatically and under the most severe conditions which can arise in service. For this, the valve or valves must have a relieving capacity at least equal to the boiler evaporation under these conditions. If it has not this capacity, the boiler pressure will continue to rise, although the valve is blowing, with a strain to the boiler and danger of explosion consequent to over-pressure. Thus, with the exception of the requisite mechanical reliability, the factor in a safety valve bearing the most vital relation to its real safety is its capacity.

2 It is the purpose of this paper to show an apparatus and method employed to determine safety valve lifts, giving the results of tests made with this apparatus upon different valves; to analyze a few of the existing rules or statutes governing valve size; and to propose a rule, giving the results of a series of direct capacity tests upon which it is based; to indicate its application to special requirements; and finally its general bearing upon valve specifications.

3 Two factors in a safety valve geometrically determine the area of discharge and hence the relieving capacity:—the diameter of the inlet opening at the seat and the valve lift. The former is the nominal valve size, the latter is the amount the valve disc lifts vertically from the seat when in action. In calculating the size valves to be placed on boilers, rules which do not include a term for this valve lift, or an equivalent, such as a term for the *effective* area of discharge, assume in their derivation a lift for each size valve. Nearly all existing rules and formulae are of this kind, which rate all valves of a given nominal size as of the same capacity.

4 To find what lifts standard make valves actually have in prac-

Presented at the monthly meeting (Feb. 1909) of The American Society of Mechanical Engineers. All papers are subject to revision.

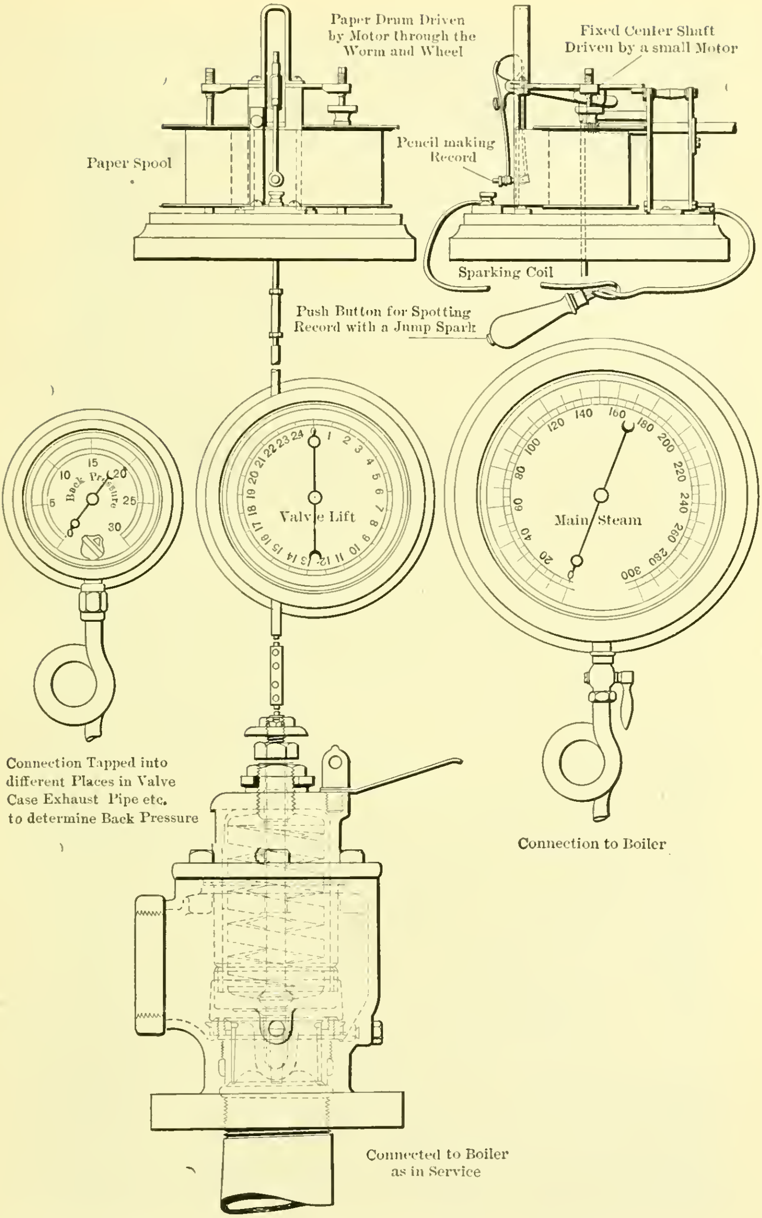


FIG. 1 SAFETY VALVE LIFT RECORDING APPARATUS

tice, and thus test the truth or error of this assumption that they are approximately the same for the same size valve, an apparatus has been devised and tests conducted upon different makes of valves. With this apparatus not only can the valve lift be read at any moment to thousandths of an inch, but an exact permanent record of the lift during the blowing of the valve is obtained, somewhat similar to a steam engine indicator card in appearance and of a quite similar use and value in analyzing the action of the valve.

5 As appears in Fig. 1 the valve under test is mounted upon the boiler in the regular manner, and a small rod is tapped into the top end of its spindle, which rod connects the lifting parts of the valve directly with a circular micrometer gage, the reading hand of which indicates the lift upon a large circular scale or dial. The rod through this gage case is solid, maintaining a direct connection to the pencil movement of the recording gage above. This gage is a modified Edson recording gage with a multiplication in the pencil movement of about 8 to 1, and with the chart drum driven by an electric motor of different speeds, giving a horizontal time element to the record. The steam pressures are noted and read from a large test gage graduated in pounds per square inch, and an electric spark device makes it possible to spot the chart at any moment, which is done as the different pound pressures during the blowing of the valve are reached. The actual lift equivalents of the pencil heights upon the chart are carefully calibrated so that the record may be accurately measured to thousandths of an inch.

6 In testing, the motor driving the paper drum is started and the pressure in the boiler raised. The valve, being mounted directly upon the boiler, then pops, blows down and closes under the exact conditions of service, the pencil recording on the chart the history of its action.

7 With this apparatus, investigations and tests were started upon seven different makes of 4-in. stationary safety valves, followed by similar tests upon nine makes of muffler locomotive valves, six of which were $3\frac{1}{2}$ in., all of the valves being designed for and tested at 200 lb. The stationary valve tests were made upon a 94-h.p. water-tube boiler made by the Babcock & Wilcox Co. (See Fig. 2.) The locomotive valve tests were made upon locomotive No. 900 of the Illinois Central R. R., the valve being mounted directly upon the top of the main steam dome. (See Fig. 4 and 5.) This locomotive is a consolidation type, having 50 sq. ft. of grate area and 2953 sq. ft. of heating surface. Although a great amount of addi-

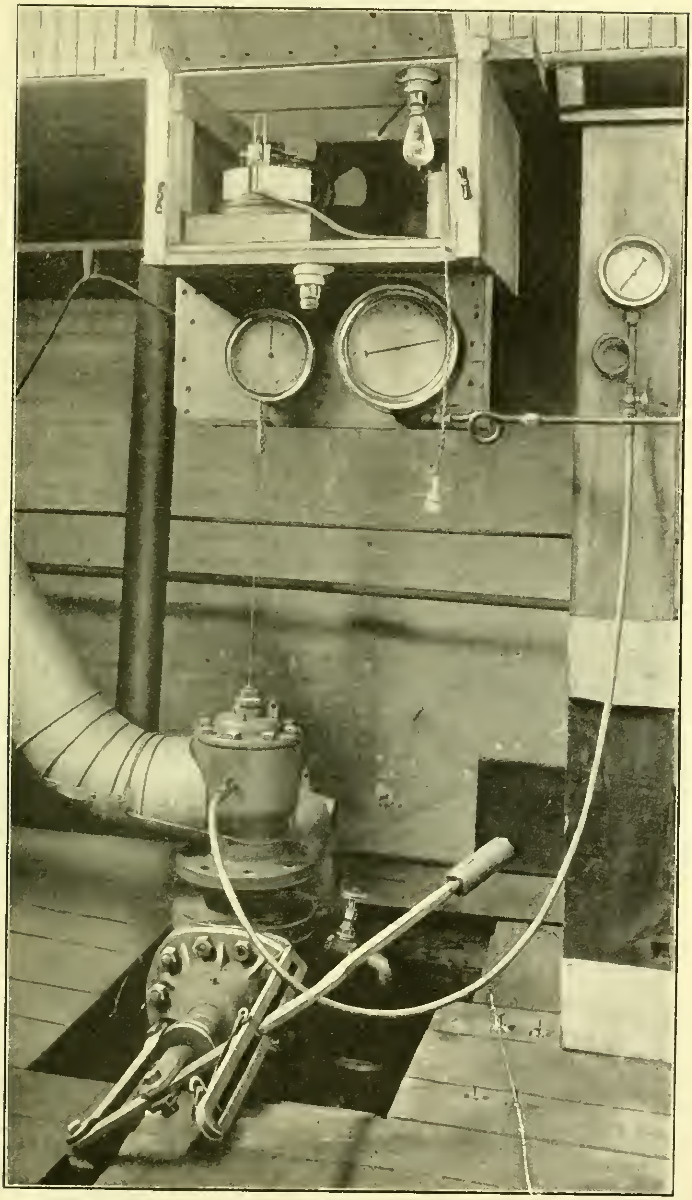


FIG. 2 VALVE LIFT APPARATUS AS USED WITH THE STATIONARY TEST BOILER AT BRIDGEPORT, CONN.

tional experimenting has been done, only the results of the above tests will be quoted here. These lift records show (with the exception of a small preliminary simmer, which some of the valves have) an abrupt opening to full lift and an almost equally abrupt closing when a certain lower lift is reached. Both the opening and closing lifts are significant of the action of the valves. (See Fig. 3.)

8 The results of the 4-in. iron body stationary valve tests summarized are as follows: of the seven valves the average lift at opening was 0.079 in. and at closing 0.044 in., or excluding the valve with the highest lifts, the averages were 0.07 in. at opening and 0.037 in. at closing. The valve with the lowest lifts had 0.031 in. at opening and 0.017 in. at closing, while that with the highest had 0.137 in. and 0.088 in. Expressing the effective steam-discharge areas of the

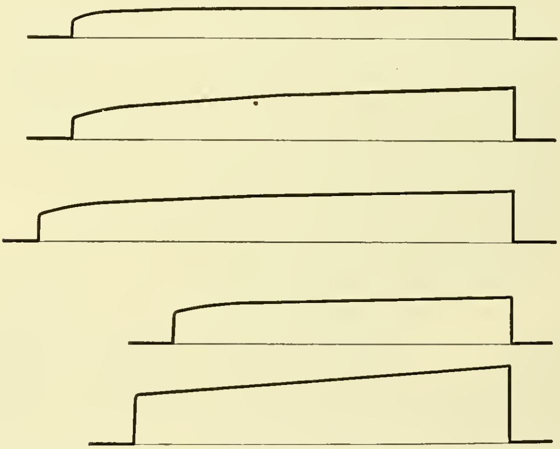


Fig. 3 Typical Valve-Lift Diagrams

valves taken at their opening lifts as percentages of the largest obtained, the smallest had 31.4 per cent, the next larger 40.8 per cent, and the next 46.6 per cent. Of the six $3\frac{1}{2}$-in. muffler locomotive valves the summarized lifts are as follows: average of the six valves, 0.074 in. at opening and 0.043 in. at closing. Average excluding the highest, 0.061 in. at opening and 0.031 in. at closing. The lowest lift valve had 0.04 in. opening and 0.023 in. closing; the highest, 0.140 in. opening and 0.102 in. closing. As percentages of the largest effective steam-discharge area, the smallest was 36.4 per cent, the next larger 39.8 per cent, and the next 46.4 per cent. In both the

stationary and locomotive tests, the lowest lift valve was flat-seated, which is allowed for in the above discharge area percentages.

9 The great variation—300 per cent—in the lifts of these standard valves of the same size is startling and its real significance is apparent when it is realized that under existing official safety valve rules these valves, some of them with less than one-third the lift and capacity of others, receive the *same* rating and are listed as of equal relieving value. Three of these existing rules are given as an illustration of their nature; the United States Supervising Inspectors

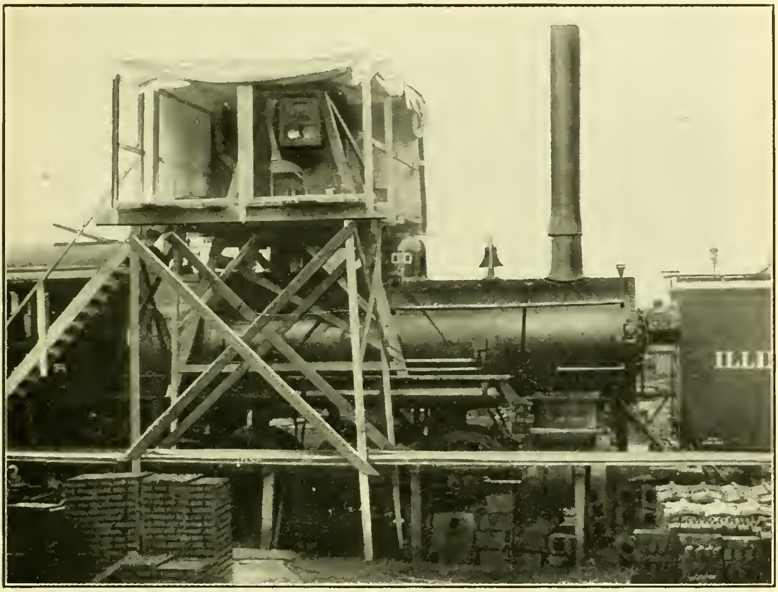


FIG. 4 VALVE LIFT APPARATUS AS ERECTED FOR LOCOMOTIVE TESTING AT BURNSIDE, ILL.

Rule, the Boiler Inspection Rule of Philadelphia and that of the Board of Boiler Rules of Massachusetts.

RULE OF UNITED STATES BOARD OF SUPERVISING INSPECTORS

$$A = 0.2074 \times \frac{W}{P}$$

A = area of safety valve in square inches per square foot of grate surface.
W = pounds of water evaporation per square foot of grate per hour.
P = boiler pressure (absolute).

10 In 1875 a special committee was appointed by the United States Board of Supervising Inspectors to conduct experiments upon safety valves at the Washington Navy Yard. Although the pres-

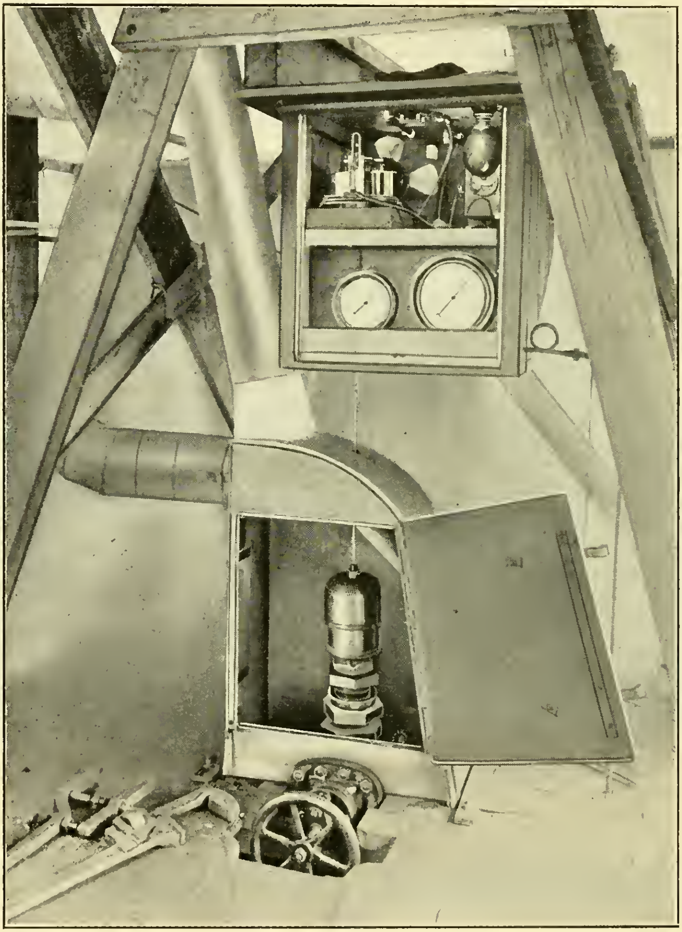


Fig. 5 Detail of Lift Apparatus at Burnside, Ill., Showing Locomotive Valve

sures used in these experiments (30 x 70 lb. per square inch) were too low to make the results of much value today, one of the conclusions reported is significant:

a That the diameter of a safety valve is not an infallible test of its efficiency.

b That the lift which can be obtained in a safety valve, other conditions being equal, *is* a test of its efficiency.

11 The present rule of the board, as given above, formulated by Mr. L. D. Lovekin, Chief Engineer of the New York Shipbuilding Co., was adopted in 1904. Its derivation assumes practically a 45-deg. seat and a valve lift of $\frac{1}{32}$ of the nominal valve diameter. The discharge area in this rule is obtained by multiplying the valve lift $\frac{D}{32}$ by the valve circumference $(\pi \times D)$ and taking but 75 per cent of the result to allow for the added restriction of a 45-deg. over a flat seat. The 75 per cent equals approximately the sine of 45 deg. or 0.707. This value for the discharge area $\left(\text{i.e., } 0.75 \times \pi \times \frac{D^2}{32}\right)$ is substituted directly into Napier's formula for the flow of steam, $w = a\,\frac{P}{70}$. Thus in the valves to which this rule is applied the following lifts are assumed to exist: 1-in. valve, 0.03-in.; 2-in. valve, 0.06-in.; 3-in. valve, 0.09 in.; 4-in. valve, 0.13 in.; 5-in. valve, 0.16 in.; 6-in. valve, 0.19 in.

12 Referring back to the valve lifts given in Par. 8, it is seen that the highest lift valve agrees very closely with the lift assumed in the rule for 4-in. valves, and if the valve lifts of the different designs were more uniformly of this value or if the rule expressly stipulated either that the lift of $\frac{1}{32}$ of the valve diameter actually be obtained in valves qualifying under it, or that an equivalent discharge area be obtained by the use of larger valves, the rule would apply satisfactorily to that size of valve. However, the lowest lift valve actually has but $\frac{1}{4}$, the next larger less than $\frac{1}{2}$, and the average lift of the valves, excluding only the highest, which average is 0.07 in., is but 56 per cent of the lift assumed in the rule for these 4-in. valves.

MASSACHUSETTS RULE OF 1909

$$A = \frac{w \times 70}{P} \times 11$$

A = area of safety valve in square inches per sq. ft. of grate surface.

w = pounds of water evaporation per square feet of grate surface per second.

P = boiler pressure (absolute) at which valve is set to blow.

13 One of the most recently issued rules is that contained in the pamphlet of the new Massachusetts Board of Boiler Rules, dated March 24, 1908. This rule is merely the United States rule given above with a 3.2 per cent larger constant and hence requiring that amount larger valve. The evaporation term is expressed in pounds per second instead of per hour and two constants are given instead of one, but when reduced to the form of the United States rule it gives $A = 0.214 \times \frac{W}{P}$. Figuring this back as was done above with the United States rule, and taking the 75 per cent of the flat seat area as there done, this rule assumes a valve lift of $\frac{1}{33}$ of the valve diameter instead of the $\frac{1}{32}$ of the United States rule. This changing of the assumed lift from $\frac{1}{32}$ to $\frac{1}{33}$ of the valve diameter being the only difference between the two rules, the inadequacy of the United States rule just referred to applies to this more recent rule of the Massachusetts Board.

PHILADELPHIA RULE

$$a = \frac{22.5\,G}{p + 8.62}$$

a = total area of safety valve or valves in square inches.
G = grate area in square feet.
p = boiler pressure (gage).

14 The Philadelphia rule now in use came from France in 1868, where it was the official rule at that time, having been adopted and recommended to the city of Philadelphia by a specially appointed committee of the Franklin Institute, although this committee frankly acknowledged in its report that it "had not found the reasoning upon which the rule had been based." The area a of this rule is the effective valve opening, or as stated in the Philadelphia ordinance of July 13, 1868, "the least sectional area for the discharge of steam." Hence if this rule were to be applied as its derivation from the French requires, the lift of the valve must be known and considered whenever it is used. However, the example of its application given in the ordinance as well as that given in the original report of the Franklin Institute committee, which recommended it, shows the area a applied to the nominal valve opening. In the light of its derivation, this method of using it takes as the effective discharge area the valve opening itself, the error of which is very great. Such use, as specifically stated in the report of the committee above referred to,

assumes a valve lift at least $\frac{1}{4}$ of the valve diameter, i.e., the practically impossible lift of 1 in. in a 4-in. valve. Nevertheless, this is exactly the method of use indicated in the text of the ordinance.

15 The principal defect of these rules in the light of the preceding tests is that they assume that valves of the same nominal size have the same capacity and they rate them the same without distinction, in spite of the fact that in actual practice some have but $\frac{1}{3}$ of the capacity of others. There are other defects, as have been shown, such as varying the assumed lift as the valve diameter, while in reality with a given design the lifts are more nearly the same in the different sizes, not varying nearly as rapidly as the diameters. And further than this, the lifts assumed for the larger valves are nearly double the actual average obtained in practice.

16 The direct conclusion is this, that existing rules and statutes are not safe to follow. Some of these rules in use were formulated before, and have not been modified since, spring safety valves were invented, and at a time when 120 lb. was considered high pressure. None of these rules takes account of the different lifts which exist in the different makes of valves of the same nominal size, and they thus rate exactly alike valves which actually vary in lift and relieving capacity over 300 per cent. It would therefore seem the duty of all who are responsible for steam installation and operation to leave the determination of safety valve size and selection no longer to such statutes as may happen to exist in their territory, but to investigate for themselves.

17 The elements of a better rule for determining safety valve size exist in Napier's formula for the flow of steam, combined with the actual discharge area of the valve as determined by its lift. In Steam Boilers, by Peabody & Miller, these principles in determining the discharge of a safety valve have already been indicated. The uncertainty of the coefficient of flow, that is, of the constant to be used in Napier's formula when applied to the irregular steam discharge passages of safety valves, has probably been largely responsible for the fact that this method of obtaining valve capacities has not been more generally used. To determine what this constant or coefficient of flow is, and how it is affected by variations in valve design and adjustment, an extended series of tests has recently been conducted by the writer at the Stirling Department of the Babcock & Wilcox Co., at Barberton, Ohio.

18 A 373-h.p. class K. No. 20 Stirling boiler, fired with a Stirling chain grate, with a total grate area of 101 sq. ft., was used. This

boiler contained a U-type superheater designed for a superheat of 50 deg. fahr. The water feed to this boiler was measured in calibrated tanks and pumped (steam for the pump being furnished from another boiler) through a pipe line which had been blanked wherever it was impossible to detect and prevent leakage with stop valves and intermediate open drips. The entire steam discharge from the boiler was through the valve being tested, all other steam connections from the boiler being either blanked or closed with stop valves beyond which were placed open drip connections to indicate any leakage. A constant

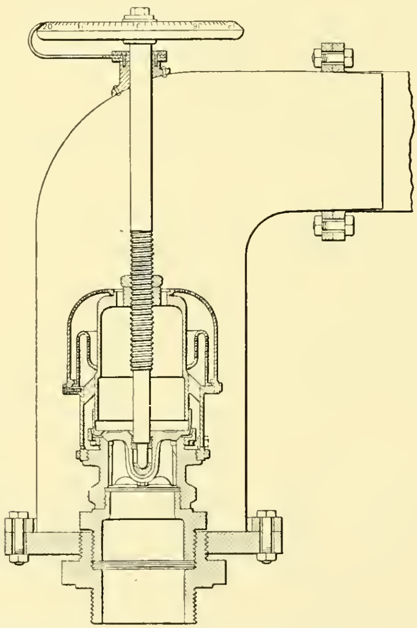


Fig. 6 Arrangement of Valve with Mecrometer Spindle Used in the Direct-Capacity Testing at Barberton, Ohio.

watch was kept throughout the testing upon all points of the feed and steam lines, to insure that all water measured in the calibrated tanks was passing through the tested valves without intermediate loss.

19 The valves tested consisted of 3-in., $3\frac{1}{2}$-in. and 4-in. iron stationary valves, and $1\frac{1}{2}$-in., 3-in. and $3\frac{1}{2}$-in. locomotive valves, the latter with and without mufflers. These six valves were all previously tested and adjusted on steam. Without changing the position of the valve disc and ring, the springs of these valves were

then removed and solid spindles, threaded (with a 10-pitch thread) through the valve casing above, inserted. Upon the top end of these spindles, wheels graduated with 100 divisions were placed. Fig. 6 shows the arrangement used with the locomotive valves, the spindle and graduated wheel being similar to that used with the stationary valves. By this means the valve lift to thousandths of an inch was definitely set for each test and the necessity for constant valve lift readings, with that source of error, eliminated.

20 In conducting the tests three hours' duration was selected as the minimum time for satisfactory results. Pressure and temperature readings were taken every three minutes, water readings every half hour. A man stationed at the water glass regulated the feed to the boiler to maintain the same level in the boiler during the test; other men were stationed, one at the water tanks, one firing and one taking the pressure and temperature readings. Pressure readings were taken from two test gages connected about 4 in. below the valve inlet, the gages being calibrated both before and after the series of tests was run and corrections applied. In all 29 tests were run, of which 15 were 3 hours long, 4 were 2½ hours, 3 were 2 hours, and 7 of less duration.

21 Tests numbered 1 to 5 were preliminary runs of but one hour or less duration apiece, and records of them are thus omitted in the following table, which gives the lifts, discharge areas, average pressure and superheat, and the steam discharge in pounds per hour of each of the other tests. The discharge areas have been figured for 45-deg. seats from the formula, $a = 2.22 \times D \times L + 1.11 \times L^2$ where a equals the effective area in square inches, D equals the valve diameter in inches, and L equals the valve lift in inches. In tests 8 and 23, where the width of valve seat was 0.225 in. and 0.185 in. respectively, and the valve was thus slightly above the depth of the valve seat, the area was figured for this condition.

22 As previously stated, the application of these results is in fixing a constant for the flow of Napier's formula as applied to safety valves. The formula is $w = a \frac{P}{70}$ in which w equals pounds discharged per second, P equals the absolute steam pressure behind the orifice or under the valve and a equals the effective discharge opening in square inches. This may be stated as $E = C \times a \times P$; in which E equals the pounds steam discharge per hour and C equals a constant. The values of E, a and P being given for the above tests C is directly obtainable.

23 Figuring and plotting the values of this constant indicates the following conclusions:

a Increasing or altering the steam pressure from approximately 50 to 150 lb. per square inch (tests 14 and 10) does not affect the constant, this merely checking the applicability of Napier's formula in that respect.

b Radically changing the shape of the valve disc outside of the seat at the huddling or throttling chamber, so-called, does not affect the constant or discharge. In test 15 the valve had a downward projecting lip (as in Fig. 1), deflecting the steam flow through nearly 90 deg., yet the discharge was practically the same as in tests 10 and 14, where the lip was cut entirely away (as in Fig. 6), giving a comparatively unobstructed flow to the discharging steam.

c Moving the valve adjusting ring through much more than its complete adjustment range does not affect the constant or discharge. (Tests 16 and 17.)

d The addition of the muffler to a locomotive valve does not materially alter the constant or discharge. There is but 2 per cent difference between tests 10 and 13.

e Disregarding the rather unsatisfactory 1½-in. and 3-in. locomotive valve tests, the different sizes of valves tested show a variation in the constant when plotted to given lifts of about 4 per cent.

f There is a slight uniform decrease of the constant when increasing the valve lifts.

24 The variations indicated in the last two conditions are not large enough, however, to impair materially the value of a single constant obtained by averaging the constants of all the 24 tests given. The selection of such a constant is obviously in accord with the other four conditions mentioned. This average constant is 47.5, giving as the formula $E = 47.5 \times a \times P$. Its theoretical value for the standard orifice of Napier's formula is 51.4, of which the above is 92½ per cent.

25 To make this formula more generally serviceable, it should be expressed in terms of the valve diameter and lift, and can be still further simplified in its application by expressing the term E (steam discharged or boiler evaporation per hour) in terms of the boiler heating surface or grate area. For the almost universal 45-deg. seat the effective discharge area is, with a slight approximation, $L \times$ sine $45 \times \pi \times D$, in which L equals the valve lift vertically in inches and

D the valve diameter in inches. Substituting this in the above formula gives $E = 47.5 \times L \times \text{sine } 45 \times \pi \times D \times P$, or $E = 105.5 \times L \times D \times P$.

26 The slight mathematical approximation referred to consists in multiplying the ($L \times$ sine 45) by ($\pi \times D$) instead of by the exact value ($\pi \times D + \frac{1}{2}L$). To find directly the effect of this approximation upon the above constant, the values for E, L, D and P from the tests have been substituted into the above formula and the average constant re-determined, which is 108.1. The average lift of all the tests is 0.111 in. Plotting the constants obtained from the above formula in each test, as ordinates, to valve lifts, as abscissae, obtaining thus the slight inclination referred to in Par. 23 *f*, and plotting a line with this inclination through the above obtained average constant 108.1, taken at the 0.111-in. average lift, gives a line which at a maximum lift of say 0.14 in. gives a constant of just 105. At lower lifts this is slightly larger. Hence 105 would seem to be the conservative figure to adopt, as a constant in this formula for general use, giving

$$E = 105 \times L \times D \times P$$

This transposed for D gives:

$$D = 0.0095 \times \frac{E}{L \times P}$$

Note that the nominal valve area does not enter into the use of this formula and that if a value of 12, for instance, is obtained for D it will call for two 6-in. or three 4-in. valves. For flat seats these constants become 149 and 0.0067 respectively.

27 The fact that these tests were run with some superheat (an average of 37.2 deg. fahr.) while the majority of valves are used with saturated steam, would, if any material difference exists, place the above constants on the safe side. The capacities of the stationary and locomotive valves, the lift test results of which are summarized in Par. 8, have been figured from this formula, taking the valve lifts at opening, and in pounds of steam per hour are as follows:

Of the seven 4-in. iron body stationary valves, the average capacity at 200 lb. pressure is 7370 lb. per hour, the smallest capacity valve (figured for a flat seat) has a capacity of 3960 lb., the largest 12,400 lb., and of the six $3\frac{1}{2}$-in. muffler locomotive valves at 200 lb. pressure,

the average capacity is 6060 lb. per hour, the smallest 4020 lb., the largest 11,050 lb.

28 To make the use of the rule more direct, where the evaporation of the boiler is only indirectly known, it may be expressed in terms of the boiler heating surface or grate area. This modification consists merely in substituting for the term E (pounds of total evaporation) a term H (square feet of total heating surface) multiplied by the pounds of water per square foot of heating surface which the boiler will evaporate. Evidently the value of these modified forms of the formula depends upon the proper selection of average boiler evaporation figures for different types of boilers and also upon the possibility of so grouping these boiler types that average figures can be thus selected. This modified form of the formula is

$$D = C \times \frac{H}{L \times P}$$

in which H equals the total boiler heating surface in square feet and C equals a constant.

29 Values of the constant for different types of boilers and of service have been selected. These constants are susceptible of course to endless discussion among manufacturers, and it is undoubtedly more satisfactory, where any question arises, to use the form containing term E itself. Nevertheless the form containing the term H is more direct in its application and it is believed that the values given below for the constant will prove serviceable. In applying the formula in this form rather than the original one, containing the evaporation term E, it should be remembered that these constants are based upon average proportions and hence should not be used for boilers in which any abnormal proportions or relations between grate area, heating surface, etc., exist.

30 For cylindrical multitubular, vertical and water-tube stationary boilers a constant of 0.068 is suggested. This is based upon an average evaporation of 3½ lb. of water per square foot of heating surface per hour, with an overload capacity of 100 per cent, giving 7 lb. per square foot of heating surface, the figure used in obtaining the above constant.

31 For water tube marine and Scotch marine boilers, the suggested constant is 0.095. This is based upon an overload or maximum evaporation of 10 lb. of water per square foot of heating surface per hour.

32 For locomotives the constant 0.055 was determined experi-

mentally as explained below. Special conditions to be considered in locomotive practice separate it from regular stationary and marine work. In the first place the maximum evaporation of a locomotive is possible only with the maximum draft obtained when the cylinders are exhausting up the stack, at which time the throttle is necessarily open. The throttle, being open, is drawing some of the steam and therefore the safety valves on a locomotive can never receive the full maximum evaporation of the boiler. Just what per cent of this maximum evaporation the valve must be able to relieve under the most severe conditions can only be determined experimentally. Evidently the most severe conditions obtain when an engineman after a long, hard, up-hill haul with a full glass of water and full pressure, reaching the top of the hill, suddenly shuts off his throttle and injectors. The work on the hill has gotten the engine steaming to its maximum and the sudden closing of throttle and injectors forces all the steam through the safety valves. Of course the minute the throttle is closed the steaming quickly falls off and it is at just that moment that the most severe test upon the valves comes.

33 A large number of service tests have been conducted to determine this constant. The size of valves upon a locomotive has been increased or decreased until one valve would just handle the maximum steam generation, and the locomotive heating surface being known the formula was figured back to obtain the constant. Other special conditions were considered, such as the liability in locomotive practice to a not infrequent occurrence of the most severe conditions; the exceptionally severe service which locomotive safety valves receive; and the consequent advisability of providing a substantial excess valve capacity on locomotives in this service.

34 As to the method of applying the proposed safety valve capacity rule in practice, manufacturers could be asked to specify the capacities of their valves, stamping it upon them as the opening and closing pressures are now done. This would necessitate no extra work further than the time required in the stamping, because for valves of the same size and design, giving practically the same lift, this would have to be determined but once, which of itself is but a moment's work with a small portable lift gage which is now manufactured. The specifying of safety valves by a designing engineer could then be as definite a problem as is that of other pieces of apparatus. Whatever views are held, as to the advantages of high or low lifts, there can be no question, it would seem, as to the advantage of knowing what this lift actually is, as would be shown in this

TABLE 1 SAFETY VALVE CAPACITY TESTS

Run at the Stirling Works of the Babcock & Wilcox Co., Barberton, Ohio, November 30 to December 23, 1908

Test Number	Duration of Test (Hours)	Size and Type of Valve	Adjustment Remarks	Valve Lift (Inches)	Pressure (Lbs. per Sq. In.)	Superheat (Deg. F.)	Discharge per Hour (Lbs. of Steam)	Discharge Area* (Sq. In.)	Remarks
6	3	4-in. R. F. Iron Stationary	Regular Adj., Exh. Piped	0.0695	151.7	43.6	5120	0.6226	No Back Pressure
7	3	"	"	0.139	145.4	45.1	8600	1.255	Back Pressure 2 lb.
8	3	"	"	0.180	135.7	49.2	11020	1.704	Back Pressure 3 lb., Max. Lift Test,
9	3	"	"	0.1045	149.4	41.9	7290	0.9400	Back Pressure 1 lb.
10	$2\frac{1}{2}$	$3\frac{1}{2}$-in. Locomotive Type R	Regular Adj. Without Muffler	0.140	146.7	39.0	8685	1.109	
11	3	"	"	0.070	152.5	38.0	4670	0.5493	Open Locomotive Valve
12	3	"	"	0.105	150.3	41.2	6780	0.8280	
13	3	" Type S	With Muffler	0.1395	146.3	38.1	8400	1.106	Muffler Valve in this and Following Locomotive Tests
14	2	"	"	0.140	52.2	51.3	3620	1.109	Test at Low Steam Pressure
15	$2\frac{1}{2}$	Same Except with Lipped Feather	"	0.140	146.4	39.0	8600	1.109	Different Type of Valve Disc
16	3	4-in. R. F. Iron Stationary	Reg. Adj., Exh. Piped	0.140	138.5	42.3	8770	1.265	No Back Pressure, Repetition of Test 7
17	3	"	Adj. Ring One Turn $\frac{1}{16}$-in. above Reg. Position	0.140	142.0	50.1	8900	1.265	Back Pressure 3 lb. Adj. Ring Position Ch'ng'd

18	2	1½-in. Locomotive Type S	Regular Adj., with Muffler	0.107	140.8	23.0	2515	0.4272	Unsatisfactory tests; Valve too Small for Boiler
19	1	"	"	0.060	151.2	None	1550	0.2038	
20	2½	"	"	0.075	146.3	None	2025	0.2560	
21	2½	"	"	0.075	147.7	None	1975	0.2560	
22	1½	3½-in. R. F. Iron Stationary	Regular Adj., Exh. Piped	0.070	146.8	42.6	4320	0.5493	No Back Pressure
23	3	"	"	0.140	139.9	43.6	8360	1.136	No Back Pressure
24	3	"	"	0.105	141.6	48.7	6300	0.8280	No Back Pressure
25	3	3-in. R. F. Iron Stationary	"	0.130	140.1	48.4	6370	0.8846	
26	3	"	"	0.100	142.8	45.6	5160	0.6770	
27	2	"	"	0.070	142.4	29.5	3705	0.4716	
28	3	3-in. Locomotive Type S	Regular Adj., with Muffler	0.130	138.4	48.7	7060	0.8846	
29	3	"	"	0.090	139.3	43.9	4950	0.6084	

* The valves all having 45-deg. bevel seats these areas are obtained from formula

$$a = 2.22 \times D \times l + 1.11 \times l^2$$

except as in tests 8, 23, where the valve lift is greater than the depth of the valve seat, in which case the following formula is used:

$$a = 2.22 \times D \times d + 1.11 \times d^2 + \pi \times D \times (l - d)$$

a = Discharge area. l = Valve lift.
D = Valve diameter. d = Depth of valve seat.

specifying by manufacturers of the capacity of their valves. Further, as to the feasibility of adopting such a rule (which incorporates the valve lift) in statutes governing valve sizes—this would involve the granting and obtaining by manufacturers of a legal rating for their valve designs based upon their demonstrated lifts.

35 This paper has dealt with but one phase of the subject of safety valves in order that its conclusions might be drawn more clearly. The apparatus and tests shown indicate that the lifts and capacities of different make valves of the same size and for the same conditions vary as much as 300 per cent, and that there is therefore the liability of large error in specifying valves in accordance with existing rules and statutes, because these rules as shown rate all valves of one size as of the same capacity, irrespective of this variation. A simple rule is given, based upon an extended series of direct capacity tests, which avoids this error by incorporating a term for the valve lift. Finally, the method and advantage of applying this rule in practice has been briefly indicated.

DISCUSSION ON SAFETY VALVES

Mr. Luther D. Lovekin.[1] The subject of Safety Valves, while well worth the attention of the profession, has received little or no consideration from the average engineer. Various rules have been employed for determining the size of safety valves, some of which appear too crude to have been even considered, much less adopted. Of late, however, considerable attention has been given to this subject; and to my knowledge numerous tests have been made that should prove extremely interesting.

2 We all know that the function of the safety valve is to prevent the pressure of steam from rising to a dangerous point, and in order to accomplish this, the effective opening of any valve should be sufficient to discharge all the steam that the boiler can generate.

3 During the year 1903, I was asked to look into the rules and regulations concerning safety valves prescribed by the United States Board of Steamboat Inspectors. The rule in use was based on grate surface, without regard to the amount of coal burned in a given time. It served its purpose without trouble since such a thing as forced draft was then almost unknown. At the present time, however, when we are confronted with the problem of building boilers for all purposes, some of them required to burn 12 lb. of coal and others as high as 70 lb. per square foot of grate, the question of the proper size of safety valve can be determined only on the amount of evaporation.

4 Having this in view, I prepared a new set of rules based on Napier's well-known formula for the flow of steam through an orifice; concluding that while the opening through a safety valve cannot be considered as having exactly the same effect as an orifice, the difference would be so slight as to be negligible. These were presented to the Board of Supervising Inspectors at their annual meeting in Washington, and adopted by them as the standard, after careful examination. The derivation of the formula is given below:

Let

P = absolute pressure.

W = weight discharged per hour in pounds.

[1] Mr. L. D. Lovekin, Chief Engineer, N. Y. Shipbuilding Co., Camden, N. J.

A = area valve opening in square inches.
d = diameter of valve in inches.
a = area of valve of diameter d.

From Napier's rule

$$W = \frac{360\ A\ P}{7}$$

For safety-valve practice allow 75 per cent of this and restrict the lift of valve to $\frac{1}{32}$ diameter.

Then

$$W = \frac{270\ P}{7} \times \frac{\pi d^2}{32} = 4.821\ Pa$$

$$a = 0.2074\ \frac{W}{P}$$

If W represents weight of water in pounds evaporated per square foot of grate surface per hour the above formula will give the area of valve required per square foot of grate surface.

5 It will be noted that in preparing this work, the lift was based on $\frac{1}{32}$ of the diameter of the valve; and while I considered this lift within good practical limits, I have found that a number of different safety valve manufacturers differ with me in this regard. Whether the valve is restricted to $\frac{1}{32}$ of its diameter or not, however, the net area of the opening should in my mind be at least equal to that shown in the table.

6 I am not in favor of what might be termed "an excessive lift of valve," such as one-fourth of the diameter, although some of the best authorities in the inspection of steamships still ask for that lift, the British Board of Trade being one of the foremost who do so. It should be said in favor of the rules of the British Board of Trade, as well as of Lloyds and the Bureau Veritas that they demand an accumulation test in connection with all spring-loaded safety valves; as follows (Page 80, par. 128, "Spring Loaded Safety Valves to be Tested under Steam"):

7 "In no case is the surveyor to give a declaration for spring-loaded valves unless he has examined them and is acquainted with the details of their construction, and unless he has tried them under full steam and full firing for at least twenty minutes, with the feed water shut off and the stop valve closed, and is fully satisfied with the result of the test. If, however, the accumulation of pressure

exceed ten per cent of the loaded pressure, he should withhold his declaration and report the case to the Board."

8 This is undoubtedly one of the safest methods to follow in determining the size of a safety valve, as the results will be based upon facts and not upon figures.

9 There is no doubt that at the present day it is crude in the extreme to fix the size of a safety valve by specifying the diameter simply, regardless of its lift and consequently its relieving capacity, and the practice should be corrected. I would not wish to restrict the makers of valves to any one particular lift, unless, of course they could come to an agreement as to the advantage of certain definite lifts.

10 Unfortunately in accepting my formula and table of safety valves, the board failed to state in their rules that the sizes were based upon a lift of valve equal to $\frac{1}{32}$ of its diameter; and consequently have left out a most important element which I shall ask in the near future to have inserted. Following the rules of the Steamboat Inspection Service as they now exist in printed form, it is quite possible for a valve to be of the proper size in inches, and yet fall far below the actual requirements.

11 Having settled upon the proper diameter for a safety valve, according to the above formula, it will be evident that the clear area between the valve and its seat (due to having a lift equal to $\frac{1}{32}$ of its diameter) is only about $\frac{1}{11}$ of the area of the nominal diameter found by said formula. Therefore it would seem that the inlet from the boiler to the safety valve should be equal in area only to the free area between the safety valve and its seat; this would reduce the opening in the boiler to about $\frac{1}{11}$ of the area used at the present time. Experiments in this line, however, have shown that a free entrance from the boiler to the safety valve is absolutely necessary to prevent chattering. Just what this relation is I have not determined; in fact, it would depend entirely on the length of the nozzle or pipe connecting the safety valve to the boiler. In most cases safety valves are bolted either directly to the boiler or to a casting which is bolted directly to the boiler, and which forms a seat for both the safety and the stop valves, so that there would be very little to gain in reducing the inlet nozzle to a safety valve.

12 While dealing with the inlet side of a safety valve I wish to bring out a feature seldom if ever discussed in connection with safety valves, and that is the question of placing the safety valve upon the outlet end of dry pipes in boilers. These dry pipes, as is well known,

usually run along the upper part of a boiler and have slots cut in to give an area equal to the full area of the pipe. In some cases I have found the steam pressure within the boiler to be 200 lb. per square inch, while that at the outlet of the dry pipe was only 180 lb. per square inch; in other words, a drop of 20 lb. pressure took place, due to wire-drawing the steam through the slots in the dry pipe.

13 In other cases we have had 300 lb. boiler pressure in connection with water-tube boilers, and have purposely restricted the flow of steam through the dry pipe so as to cause a reduction in pressure of 50 lb. per square inch, and thus obtain a slight degree of superheat. In this latter case, however, the safety valves were applied to the boiler drum, and not in connection with the dry pipe.

14 This question of fitting dry pipes, and connecting the safety valves to their outlets, is one which should receive careful consideration, and I have found it advisable, in order to prevent excessive pressures in the boilers, to have at least 25 per cent excess area through the slots.

15 Assuming for the present the inlet of the safety valve to be of approximately the same diameter as the valve itself; so as to prevent chattering, the point of the next greatest importance is the outlet area from the safety valves; some rules insist on an outlet area equivalent to the full bore of the safety valve, which appears both inconsistent and unreasonable; for if we have only $\frac{1}{11}$ of the area for the steam to pass through at the valve seat, we certainly do not require the full area for the steam to pass to the atmosphere.[1]

16 It is almost impossible to make any close calculations for this that would suit all conditions, as a study of the various arrangements of safety valve escape pipes will show; but I think that an outlet from a safety valve equal to $\frac{1}{2}$ the area of the valve would no doubt suffice in all cases. In fact most of our United States battleships are equipped in this manner, and I think this should receive the attention of the board and others.

17 While the U. S. Cruiser Tennessee was on trial the main engines were stopped suddenly, due to trouble with one of the connecting rods. All the safety valves responded instantly, and though the steam pressure went up to 10 lb. above popping point, no trouble was experienced as the result of this sudden stoppage; proving beyond doubt that a combined area of outlet pipes equal to $\frac{1}{2}$ the area of the safety valves was sufficient to prevent an excessive

[1] The area of safety valves referred to above is the nominal area of the valve.

accumulation of pressure. This seems reasonable and might have been true with less area; a matter, however, that can be determined only by actual experiment.

Mr. Albert C. Ashton. It seems to the writer that what is most needed today is not necessarily that standard makes of pop safety valves should have a greater capacity of relief than is now furnished by them, but rather that there should be a better understanding of the proper proportioning of safety valves to boilers, for which no universal rule has as yet been recognized and adopted.

2 Mr. Whyte lays some stress on recent tests that have been made to determine the comparative capacity of pop safety valves now on the market, being doubtless, the tests referred to by Mr. Darling. While these tests show what such valves will accomplish under certain favorable conditions they have not clearly demonstrated that high-lift valves so made are a success on all applications. They certainly have shown many failures in locomotive service during the past year, and must still be classed as an experiment.

3 Under some circumstances they may be considered even dangerous, as in cases where they have lifted the water from the boiler, caused leaky tubes, as well as where they have gone rapidly to pieces on account of their harsh action.

4 Safety valves should never give such a large and sudden relief as to affect the water level in a boiler, neither should they close so suddenly as to be a shock to the boiler by the quick stoppage of the flow of steam. High-lift valves which do this are not as practical as lower lift valves which give a somewhat slower and easier relief. In other words, the most satisfactory safety-valve service is that which causes the least shock to a boiler, and yet controls closely any possibility of over-pressure. These factors should be considered in the discussion.

5 If high-lift valves were certainly an improvement over the best standard makes, safety valve manufacturers in general would change their designs, as can easily be done, and make nothing but high-lift valves The tests which Mr. Darling has explained tonight show an average lift of $\frac{1}{8}$ in. for the high-lift valves which is about double the lift of standard valves. Such high lift seems to the writer excessive, although there may be some virtue in making valves with a little higher lift than the common standard of $\frac{1}{16}$ in.

6 It is to be hoped that as a result of this meeting the Society will take up for investigation the broad question, as to the most practical

schedule or formula for determining the proper capacity of relief that safety valves should give on various-sized boilers at various pressures.

Mr. A. B. Carhart. The spring is the heart of the modern pop safety valve. The operations of a poorly-designed valve may be greatly assisted by a suitable spring, and a valve with an excellent arrangement of the other parts may be seriously handicapped by an improperly designed spring, or even transformed from a safety device to a source of danger.

2 In making a safety valve spring there are practical limitations which must be taken into account. Steel of very large diameter cannot be wound satisfactorily upon a small mandrel. A spring excessively long in proportion to its diameter and pitch may bend or buckle instead of compressing in a straight line axially; and if the number of coils be too great the reaction of the spring will set up an oscillation which will cause destructive chattering of the valve. The valve disc must not, in effect, be suspended at the end of a flexible spring, but must have behind it at all times a positive force capable of controlling its action when lifted by the escaping steam. If the spring be too short, not only will the reaction be too sudden, but the active free coils will form so small a proportion of the total length that the spring compression will be greater on one side than on the other and there will be an undesirable sidethrust on the disc guides. If the pitch be steep or the coils wound far apart, there will be room for considerable free movement and apparently a sufficient deflection of each coil to provide for the desired compression; but the fiber stress will be enormously increased and the rod may be fractured or a permanent set produced in it. On the other hand, if there are too many coils, there will not be sufficient free space between them to permit even the small compression necessary, and the spring will have insufficient reactive power.

3 The performance required of the spring in a pop safety valve is different from that expected of car springs or similar buffers. In carrying the load of a car or wagon, any unevenness of the road causes a jolting or bouncing, and the momentum of the moving car adds temporarily to the effect of its dead weight in increasing the violent action of the spring. Under severe conditions such springs are often compressed to their limit, until the coils are in solid contact, and a severe bump or jar is felt in the car itself; but the reaction of the spring, when the unevenness is past, sets the car back to its proper

position, and on the rebound it may be that the car has risen above its normal position so that the spring is drawn out in tension; after a while these waves of oscillation subside, and the car rides normally. Car springs are generally designed so that when the car is loaded in an ordinary manner the spring will be about one-half compressed. This gives some leeway for additional load in the car, and also permits the greatest movement possible above and below the normal medium position. It is believed that the condition of longest life is met when the calculated ordinary load will compress the spring one-half of its total free movement.

4 For pop valve service, on the other hand, the exact pressure load is determined by the exposed area of the disc and the steam pressure; and when the valve opens there is an additional load governed by the additional exposed area of the disc and the steam pressure, which rapidly decreases as the steam directly below the valve escapes and the boiler is relieved. Under no conceivable conditions of actual service can sufficient steam pressure be brought upon the disc to compress the spring so that the coils will be solid, metal to metal, if it has been well designed for its original fixed load; and the additional spring compression to permit the valve's opening in order to relieve the boiler is comparatively little; possibly 0.08 in., more commonly and preferably less, and never under any conditions as much as 0.12 in., or say $\frac{1}{8}$ in. the extreme lift. If after the fixed load-pressure is reached the spring has still $\frac{15}{32}$ of unused possible compression, of which less than $\frac{3}{32}$ in. will be required to accommodate the desired lift of the valve, there will still be $\frac{3}{8}$ in. more before the spring will go solid, at which point all further compression would be impossible; therefore the valve spring can be properly designed to carry its set load at much more than half of its total free compression, and nearer to its solid condition than would be wise with a car spring where the amount of motion is not limited.

5 If springs are properly proportioned, the point of greatest resilience, elasticity and reaction, securing sharp action in the valve and accurate adjustment of opening pressure, is in the last one-third of the total possible free compression, and this is the part of the spring action which should be utilized for safety valve service. I believe it proper to proportion the spring so that the set load is carried at about two-thirds or three-fourths of its total free compression, making the dimensions such that the remaining unused compression of the spring is ample for the lift of the disc and a safe margin beyond.

6 While it may be said that the springs will never be subjected to the extreme compression required to force them solid in service, yet where the working compression is such a large proportion of the total free movement, the spring might be dangerously near the point of setting or fracture unless proportioned and tempered to take the solid test. In making boiler tests the head bolt may be set down until the spring is solid, to close the valve; and if the valve is fitted with a lever, the spring may at any time be lifted or compressed an indefinite amount by that means, even to solid. I would not consider it proper to use in a valve with a lever any spring that would not safely take the solid test and was not capable of being compressed until the coils are metal-to-metal, any number of times consecutively, without showing any permanent set.

7 Otherwise there can be no mark or means to prevent the spring from being screwed down, even through ignorance, until the danger point may be once passed, and the spring then takes a permanent set, after which it becomes entirely ineffective as a valve spring, and a source of danger if its use is ignorantly continued.

8 One prominent manufacturer of safety valves requires all springs to be designed to take this solid test indefinitely. After the springs are made and tempered they are closed solid in a press at least three times; and again before they are put into valves for service, at the time when the ends are dressed and fitted, they are again tested three times in the same way and the compression is noted at the load for which they are designed. If any spring sets, even temporarily, as much as $\frac{1}{16}$ in., or if there is much variation in the compression at normal load, it is condemned and rejected. Out of the great number of valve springs made and tested every year under these conditions less than one-third of one per cent are rejected, which shows the requirements to be commercially practicable and the method of calculation and design sound and conservative.

9 Springs of comparatively poor design, if well made of proper steel, heated uniformly to the temperature for working and tempered skillfully, are better than springs of better dimensions but improperly made. In most small shops where springs are wound by hand, the long bar of steel must be heated in short sections in a small furnace or forge fire, winding about a foot of the steel at each operation, drawing the bar by hand-tongs around a cold mandrel and then sticking the remainder of the straight bar again into the fire until it is soft enough to wind another coil or two. Each foot of the steel has then been heated to a different temperature, and where the heated sections

have overlapped, the steel is likely to be burned. The same difficulty arises in tempering, where it is necessary to secure even heating Bars measure from 5 to 12 ft. long for valve springs of the larger sizes, and for locomotive valves the lengths would be about 4 to 6 ft. The whole bar should be evenly heated at one time, without being exposed to any direct de-carbonizing flame or forge blast, then wound accurately and quickly at one operation, and plunged in the tempering bath at exactly the proper moment.

10 These springs should be wound of a special grade of steel, kept up to standard specifications, in the various sizes and shapes of bar required for different loads and pressures; and although they are wound in the same general manner and have much the same outward appearance as ordinary coiled helical springs used for car springs and other commercial purposes, in reality they are very different in treatment and character, and proper results can never be obtained if springs of ordinary steel are substituted. No railroad should attempt to use car springs of similar shape that may be on hand, or to buy springs for safety valves by specifying simply the measured dimensions.

11 In measuring springs, it is the custom and better practice to state first the inside or mandrel diameter, then the free length of the finished spring and last the diameter and form of the steel rod used, the measurement of the cross-section being that of the straight bar before winding. For long springs it is sometimes necessary to use a taper mandrel to facilitate the drawing-off of the spring, although generally the slight natural expansion of the spring after winding will sufficiently release it; where the mandrel is tapered, the mean diameter, approximately half-way between the two ends, is the dimension to be specified. The over-all outside diameter will generally be slightly more, and the outer face of the coiled square steel will be less, than the commercial dimensions would indicate.

12 It is plain that we can get no more work out of a spring in reaction than is put into it, and the more compression put into a spring, the more work it will return, and the sharper and more positive will its action be in controlling the valve. The way to get proper work out of a spring is to put force into it in effective stress.

13 Low fiber stress is not a measure of safety but of ineffectiveness. To develop properly the resilience of the most trustworthy and suitable steel available today requires a stress that would be inadmissible with material of inferior temper or uncertain quality, and subject to ordinary commercial defects. Experience shows that springs may best be stressed at from 60,000 to 75,000 lb. per sq. in.

at the fixed load, which should compress the spring about 70 per cent of its total possible free movement. The remaining movement should be three or four times the further lift of the valve in opening. This is a low stress for the material and gives safe working limits. Under the same formula the stress when the spring is solid will not exceed 100,000 lb. per sq. in.

14 The limit of elasticity, beyond which a permanent set occurs, is different for torsion and for elongation and independent of the tensile strength, and for steel of the proper characteristics for spring-making this torsional elasticity is relatively high. Car-springs have sometimes been calculated upon a fiber stress as low as 30,000 lb. per sq. in. at normal load, and this may have seemed reasonable for common grades of steel under circumstances where the springs might frequently be subjected to extreme compression or extension. But with the material used today a fiber stress of 80,000 lb. is generally recommended. This is not a question of keeping within limits of safety, but of stressing the steel to its point of proper efficiency. It would be absurd to expect a spring suitable for use in a valve at 200 lb. pressure to show proper performance and lift, or permit satisfactory opening and closing of the valve, at only 50 lb. pressure; its reaction and resilience could not be at all reasonably developed.

15 If a spring is designed for a fiber stress of 70,000 lb. per sq. in. at normal load, and as much as 100,000 lb. per sq. in. when compressed solid, and is made of such steel that it can remain assembled in the valve indefinitely under pressure without perceptible set, and can be compressed solid an indefinite number of times without injury, it is evident that it is used at a safer percentage of its elastic limit than springs made of less virile steel, which although designed for only 30,000 lb. per sq. in. fiber stress at normal load, will suffer a gradual set or deterioration in service or will become permanently set if tested solid.

16 Springs of bronze are notoriously inefficient and unenduring, and their depreciation and permanent set in service at comparatively low fiber stress more than balance any possible advantage of slow corrosion; and certain grades of steel may be as poorly adapted for the making of valve springs. The torsional elasticity and power depend not upon the tensile strength so much as upon the temper and resilience. Therefore some of the new alloy steels have proved disappointing for this service and the name of any alloy can not as yet be used either as a fetish or a selling-phrase.

17 Observation of many thousand springs in continuous daily

service, under severest conditions of constant use, shows that springs calculated upon a very high fiber stress are entirely reliable for indefinite periods of service and do not develop any measurable percentage of faults or fractures; the failure of valves under operating conditions attributable to such springs is practically unknown and is less than is due to the rare defects of the other structural parts.

18 Large movement of the spring in compression is undesirable; it is but a necessary means to an end, an evil to be kept within minimum limits. It would be an advantage if a satisfactory discharge area of the valve could be attained with even less spring compression than at present. Large lift of the disc is not a measure of capacity but of inefficiency; for the valve which releases the steam with the least proportional lift or spring compression is to that degree the more efficient for its purpose and at the same time more safe and reliable.

19 The specifications which require valve seats to be made of non-corrosive metal, and the rules which compel every valve to be tried and lifted by the lever every day, aim to overcome the ever-present danger that the valve may stick upon its seat and fail to open at the critical moment; but the greatest cause of the sticking of the valve, when it does occur, is not corrosion of the seat face but the binding friction of the disc-guides against the side of the well or throat of the valve. This cocking or binding effect can be decreased by any modification of design which will reduce the diameter of the cylindrical guide, or which will bring the guiding surface close to the plane of the seat, both of which would reduce the moment of the friction or cocking stress. Any device which reduces the lift of the disc and the spring movement to the least possible amount will also reduce the eccentric spring action and its effect, and of course any valve design which contemplates an unnecessarily large lift or compression disadvantageously magnifies this effect. It is perhaps important to point out that as the primitive and still common form of safety valve has a seat opening beveled at an angle of 45 deg., the effective passage through the seat is measured by the sine of 45 deg. and is approximately only 0.7 of the actual vertical lift or compression of the spring when the valve opens, so that the spring must necessarily compress about $1\frac{1}{2}$ times the effective lift, and even this does not always afford a free passage for the steam to the air where there is vertical overlap of the regulating ring against the lip of the disc in order to increase the lift against the greater pressure of the shortening spring.

20 In the well-known annular type of valve, the area of the disc

open to the constant pressure of the steam is approximately only four-fifths of the total initial area of the disc under load in the bevel-seated form of valve having the same diameter and seat circumference, therefore the use of the familiar annular, flat-seated valve is the logical way to reduce to a minimum all the difficulties of spring making, especially where the space available for the spring is absolutely limited by the over-all dimensions permitted by locomotive builders and boiler-makers; for the spring need thus be of dimensions and strength to carry only four-fifths of the load necessary in the lip-type of valve; the vertical lift and spring compression require to be only 0.7 as much, or for the same lift will give $1\frac{1}{2}$ times as much discharge area. No preliminary lift is required to relieve the overlap of an adjusting ring, for the work of giving to the disc its sudden pop lift is performed by an auxiliary steam discharge by-passed through the central passages. This by-passed or auxiliary discharge adds its volume to the main discharge capacity and leaves an absolutely unrestricted and unthrottled free escape for the main flow of the released steam directly to the open air, without any tortuous expansion chamber or deflecting ring; the outlet is across a flat seat which not only utilizes the full vertical lift but gives a discharge opening of cylindrical form with efficient rounded edges, and has the further advantage that it is impossible for it to jam or stick; it is easily re-faced by rubbing on a face-plate instead of grinding to a bevel, and as the disc can be made entirely without the ever-cocking and sticking guides, the spring can be utilized to the greatest possible degree. My emphasis upon this point of spring limitation and the helpful effect of suitable valve-seat design is because attention has not been generally called to its importance and experience has shown the serious difficulties which may be thus minimized if not entirely avoided.

21 It is not within my purpose to recommend any definite formula for the calculation of helical springs. My investigations have led me to believe that there are not in this country today many men who have experienced the fortuitous concurrence of time, inclination, business necessity and proper manufacturing and testing facilities to lead them to develop a practical working formula very far beyond the very unsatisfactory rules laid down in the handbooks. Experiments have been carried out upon springs wound of comparatively small wire, but everyone who has had occasion to use the conventional formulae must have realized that no matter how well they cover a few types of car-springs within a limited range, they lead us far astray in this special branch of the problem; especially in cases where

the limitations upon the free length of the spring will not permit the use of either round or square bars and some special flat or rectangular section must be used to secure the required area of steel and still leave room for movement between the coils. One engineer to whom I applied for advice replied:

22 "I would say, in reference to the question raised by you, that we do not consider it good practice to allow a stress of over 95,000 or 100,000 lb. for valve springs, although we have in our various experiences stressed springs as high as 145,000 and 150,000 lb., but we do not under any circumstances recommend this or any approximate stresses for the extreme service to which valves are subjected. A long time ago we demonstrated that while various published formulae are correct within certain limits for springs made of round steel, they were far from correct for springs made of squares and special sections."

23 Nearly every engineer of education and experience would be qualified to suggest at least one apparently simple and more or less obvious improvement in the design of safety valves or springs, but nearly every such possible detail will be found to be old. Almost every conceivable device or modification has been the subject of a patent, and most of these have been thoroughly tried, with much expense and enthusiasm, before being condemned and discarded. The various subterfuges of double or concentric springs, one more flexible than the other, of spiral springs with coils of increasing diameter, whose first movement in compression is rapid until the smaller and stiffer coils are brought into action, springs suspended in all sorts of universal bearings, and every method of end bearing and fitting, have all been tried and abandoned by almost every maker.

Mr. E. A. May.[1] In view of recent legislation by various states and municipalities with reference to boiler inspection, and the size of safety valves, this question is assuming considerable importance in the minds of manufacturers of low-pressure cast-iron house-heating boilers. Mr. William Barnet Le Van's valuable treatise on Safety Valves, their History, Antecedents, Inventions and Calculations, has made it seem unnecessary to consider the various formulae for calculating the size of safety valves, and it will rather be the purpose of the writer to bring into prominence the various factors which enter into the make-up of the algebraic equations and which determine the proper size of safety valves.

[1] Mr. E. A. May, Mechanical Engineer, the American Radiator Co., Chicago.

2 There are so few data available applying strictly to low-pressure heating boilers that original research is necessary and it is unfortunate that when such investigation is undertaken by any boiler manufacturer, the data secured are often considered prejudiced by manufacturers of other types of boilers.

FUNCTIONS OF THE SAFETY VALVE

3 Many diverse opinions exist as to the functions of the safety valve, and the question should be discussed from as many viewpoints as possible that there may remain at least a groundwork upon which to build a theory which shall be logical and fully demonstrable.

4 Whether a safety valve should be called upon to exhaust all the steam generated by the boiler at its maximum capacity, or only to care for the excess generated over and above a predetermined amount, offers opportunity for profitable discussion, and this point must be established in order to form a standard for general practice by manufacturers of low-pressure boilers. Practice has demonstrated that a safety valve on a low-presssre boiler is rarely called upon to exhaust all the steam-generating capacity. This is due to several conditions:

a In the majority of heating plants, the full amount of radiation is almost always in service, caring for a large percentage of the steam generated, and even when the radiation is nearly all cut out there is still circulation through the piping.

b Practically every steam boiler used in low-pressure work, which rarely calls for gage pressure in excess of 2 lb., has its damper regulator which, when properly set, checks combustion when 2-lb. pressure is reached.

c Chimney conditions in the majority of heating plants make it almost impossible to drive the boiler to its maximum steam-generating capacity, i.e., the maximum capacity obtainable with every condition exactly right.

5 In practically all house installations at least two of these conditions exist, and in a majority all three, so that we would have to select a valve out of all proportion to actual requirements in order to exhaust all the steam which might be generated by the boiler under its full steam-generating capacity and under ideal conditions.

MAXIMUM CAPACITY

6 It may be argued that if one boiler is installed under ideal conditions, a valve suitable for those conditions should be installed on all boilers of the same size. This brings us to a consideration of maximum capacity and how it is established: whether (1) by the heating surface of the boiler alone; (2) by the grate surface; (3) by the fuel-carrying capacity; (4) by the rate of combustion; or (5) by all combined. Scarcely any two manufacturers of low-pressure house-heating boilers agree in this particular. One may rate solely on the area of heating surface, another on the grate surface, and still another on the amount of fuel the grate will carry, but the writer believes that none of these factors should be considered alone.

7 Many of the rules in force as to the proper size of safety valves are based on the amount of grate surface contained in the boiler. The office of a grate is to furnish a support for the fuel and to admit air for combustion. The fuel-burning capacity of 1 sq. ft. of grate, where the chimney flue is of ample capacity, is controlled by the size and length of the internal gas passages or flues and the quantity and disposition of the heating or absorbing surface. Where the grate surface is too large, air in excess of requirements is likely to enter the fuel and cool the gases liberated by combustion. If there is excess flue surface, giving long gas travel with the attendant frictional resistance, insufficient air enters the fuel chamber, and the latent heat or stored energy of the fuel is not fully liberated.

8 Large grate area and indifferent draft form a bad combination, making it impossible to maintain good combustion over the entire area of grate. In such cases, the size of grate should be reduced, concentrating the draft on a smaller area. It is the writer's opinion that grate area alone is not the basis on which to establish the size of safety valves.

9 While the amount of steam generated is in direct relation to the rate of combustion (i.e., the amount of coal burned per square foot of grate per hour), yet if different types of boilers were selected of practically the same grate area, the writer is confident no two would have the same capacity. In one the amount, position, and arrangement of the heating surface might make it impossible to burn more than 7 lb. of fuel per square foot of grate per hour, with 6 lb. of water evaporated per pound of fuel, which is below normal. Another might have a maximum rate of combustion of 10 lb., with an evaporative power of 8 lb. of water, and another a maximum rate

of combustion of 12 lb., with an evaporative power of 9 lb. of water. It would be unreasonable either to expect or require all three boilers to have the same size safety valve. Before a definite rule as to the size of a safety valve is formulated, therefore, the factors to be used in establishing the maximum rate of combustion and calorific value should be determined.

NEED FOR A COMMON BASIS

10 It is not the purpose of the writer to go into the merits or demerits of boiler rating as especially applied to cast-iron house-heating boilers; but it would seem that there should be a common basis arrived at by manufacturers of house-heating boilers for their ratings, before any attempt is made to establish the size of safety valve required. The relation of valves for low-pressure heating work to the actual capacity of the boiler is so close than one can scarcely be considered without the other.

PROPER SIZE OF THE SAFETY VALVE

11 In view of the wide variation in methods employed by manufacturers in ratings of boilers, as well as in the rules employed by users of safety valves, it would be difficult to select a proper size valve based on grate dimensions only. If valve manufacturers would indicate, in addition to the size of the valve, its capacity at different adjustments for exhausting steam, it would help materially, not only from the standpoint of the boiler manufacturer but of those whose duty it is to inspect the safety valve, and would further aid in the matter of legislation. Valves could in fact be designed and sold on their exhaust capacity without regard to specific size, i. e., owing to variation in design, one valve might have a larger diameter with a lesser lift than another, while their capacity for exhaust might be identical.

12 The simplicity of this method will be appreciated by anyone considering the rules and formulae in effect at present. If the law specified, however, that for a certain evaporative power or rating of boiler a certain exhaust capacity should be maintained in the valve, each manufacturer could determine for himself the proper valve to use.

Mr. H. O. Pond. The engineer about to design a boiler installation finds himself confronted by an array of rules covering the appli cation of safety valves, no two of which, if applied to a case, will give the same results, and the correctness of any of which may be questioned. The size and number of safety valves installed with any boiler have depended in the past, therefore, either upon the person making the installation or upon a more or less effective police or insurance regulation.

2 This practice has not perhaps been as serious a menace to life and property and the proper operation of plants, however, as it has recently become. For a number of years the tendency has been to force boilers further and further beyond the standard ratings, and to get the maximum possible capacity out of the boiler installation, so that valves which may have been of the right size for boilers operating on low ratings undoubtedly would not be correctly proportioned for boilers forced to capacities as high as 200 per cent of rating. The use of the superheater has also introduced an additional factor which must be considered when deciding upon a safety valve installation.

3 The absolute absence of reliable data relative to safety valve performance, and the proportioning of valves for a given service, was brought forcibly to my attention something more than a year ago, in connection with the design of some special boilers of large capacity, equipped with superheaters. When asked for data relative to the capacities of their valves, none of the manufacturers were able to furnish any definite information.

4 It is necessary to know how much steam can be discharged through a given valve at a given pressure and temperature, in order to properly determine the size or number of valves to be used under given conditions. The quantity of steam which can be discharged through valves of the same "catalogue" size, but of different design and manufacture, undoubtedly varies considerably. No two manufacturers use just the same lift of valves of the same catalogue size, nor is the design of seat, muffled ring and ports the same. These points must necessarily effect the discharge through the valve, and they are not properly considered in the present rules governing safety valve practice.

5 What we must know in order to apply safety valves to boilers intelligently is, above all, how many pounds of steam at a given pressure and temperature can be discharged in a given time through the particular valve which it is desired to use; some idea can then be gained as to the number of valves to be installed.

6 Feeling the necessity of getting reliable data on this subject, and that if possible the rules governing the use and application of safety valves to boilers should be revised and brought into rational working form, I have taken the matter up with several of the valve manufacturers and with the Babcock & Wilcox Co., to see if some reliable quantitative tests could be made, and the results used in checking the present rules or formulating new ones for determining the proper proportioning of safety valves to meet boiler conditions. From the papers it will be seen that considerable work has already been done with a view to obtaining some definite information relative to safety valve capacities, and other tests and experiments along the same line are now being conducted. It is hoped that through the Society a movement may be started to revise the rules governing the use of safety valves on steam boilers, and that it may also soon be possible to obtain from the manufacturers a statement of ratings of valves based on capacity of discharge rather than on catalogue size.

Mr. F. J. Cole. Several reasons may be cited in explanation of the apparent disregard of definite rules governing the application of safety valves to locomotives. As this condition exists not only in this country but in foreign lands, it may be of interest to quote from the letter of a prominent locomotive builder abroad:

I may say that we do not, in fact I do not think any locomotive builders in this country, either private firms or railways, adopt any special practice with regard to size and capacity of safety valves for locomotive boilers.

You are probably aware that the "Ramsbottom" duplex safety valve is almost universally adopted in this country and, with the exception of your own, almost throughout the world. When these safety valves were introduced on the London & North Western Railway in 1858, they were made 3 in. in diameter at the seat, each. In order to show you how little regard is taken in this country to any proportion of area of safety valves to any other part of the locomotive, the size of safety valve I name has been perpetuated, notwithstanding the fact that boilers have nearly double the capacity, and the pressures have been increased 50 per cent. Further, as an illustration of the perfunctory manner in which this matter of safety valves is being dealt with, we have constructed boilers of capacity of no more than that on which two 3-in. safety valves have been fixed with two sets of duplex safety valves of 4½ in. diameter, which means, of course, four separate valves, each that diameter. As a matter of fact, we do not attach much importance to the capacity of a safety valve, as we are very particular with our drivers in censuring them for allowing their engines to blow off steam to any extent. We think a safety valve should be looked upon as merely an instrument to indicate that more water should be injected into the boiler, or less fuel should be put on, and in practice, careful drivers seldom allow their engines to blow off

steam. Exception is made in cases where locomotives may be working hard with a heavy load up-hill and with the necessary fierce fire, coming unexpectedly upon signals against the driver, in which case the shutting of the regulator necessarily involves an accumulation of steam which the safety valves have to carry away.

2 It is probable that general foreign practice for locomotive safety valves is systematized no more than in England or America. While definite rules to govern this matter are desirable, it is evident that on account of the peculiar conditions governing the draft on locomotives, the same necessity does not exist for safety valve regulation as in the case of marine or stationary boilers, the action of the exhaust automatically taking care, in a large measure, of the generation of steam.

3 Usually in urging a locomotive up a steep grade, the boiler is taxed to its utmost capacity, and the water is frequently lowered so as just to show in the lower gage cocks when the summit is reached. When steam is shut off the water is still further lowered, and it is usually necessary to put on the injectors and fill up the boiler, and this same practice has often to be resorted to when an engine is shut off suddenly, on account of a signal unexpectedly displayed, or from other causes. Furthermore, locomotive boilers are so carefully constructed, with a large factor of safety, ranging from 4 to 5, that they have ample margin of strength, and there is no cause for alarm even if the pressure goes temporarily 20 or 25 lb. above the normal blowing-off point.

4 With steam at 200 lb. pressure, the temperature is about 387 deg. fahr. At 220 lb. the temperature is about 395.5 deg. or 8.5 deg. higher. If the pressure temporarily goes 20 lb. above the normal, it means that the entire mass of water has been heated 8.5 deg. higher than before, and it is altogether probable that with this increase in pressure and temperature, most of the radiant heat in the firebox has been absorbed.

5 The writer is in favor of a thorough investigation, looking towards the formulating of definite and authoritative rules for the application of safety valves to locomotives, and he invites attention to the following suggestions for their preparation:

a The diameter, number and kind of safety valves to be based on their capacity for discharging pounds of steam per second at different pressures.

b The maximum amount of steam which the safety valves may be required to discharge when the throttle is suddenly

closed after the fires have been urged to their maximum rate, to be based on the square feet of equated heating surface, so that the relative values for evaporation for various kinds of heating surface, whether of firebox, water tubes for supporting arch brick, long and short boiler tubes between the limits of 10 and 21 ft. in length, and values for different spacing of boiler tubes, will be taken into consideration. Or, what would be simpler, some approximation of average value of heating surface, corrected to account for difference in length and spacing of tubes; the firebox heating surface in this case to be considered as a certain percentage of the whole for all sizes of locomotives.

6 A great diversity of practice exists in the spacing of flues in locomotive boilers. The variation in length ranges in common practice from 10 to 21 ft. These two conditions make the use of heating surface unequated as an absolute guide for the amount of water evaporated, somewhat unreliable. It is evident in two boilers having the same diameter and the same length between flue sheets, that one will contain a much larger amount of heating surface if the flues are spaced $\frac{11}{16}$ in. apart than the other if they were spaced 1 in., and both these figures are within the limits of what is accepted as good practice. Furthermore, heating surface based on flues of the same diameter, and say 11 ft. long, will be much more effective per foot of heating surface than if they were 21 ft. long. Fire box heating surface is, of course, very much more efficient than tube heating surface, and the water-tube heating surface for supporting firebricks is more efficient than the ordinary boiler tubes.

7 Tests show that the evaporation of boilers is somewhat independent of the tube spacing, and probably is more in direct relation to the cubical contents, as it is a matter of common knowledge that the steaming capacity of boilers does not vary in direct proportion to the amount of heating surface if a great variation exists in the spacing of the tubes.

8 The evaporation per square foot of heating surface in locomotives is a variable quantity, ranging from 6 lb. or even less to 15 or 16 lb. per square foot of heating surface per hour. On the authority of Professor Goss, from Purdue University tests, it may be stated that the evaporation in a very general way, and the draft produced by the blower and exhaust in terms of inches of water, will be approximately as follows:

1-in.	draft	will	evaporate	3.0	lb.	per	feet	of	heating	surface	per	hour
2-in.	"	"	"	6.0	"	"	"	"	"	"	"
3-in.	"	"	"	8.2	"	"	"	"	"	"	"
4-in.	"	"	"	10.0	"	"	"	"	"	"	"
5-in.	"	"	"	11.4	"	"	"	"	"	"	"
6-in.	"	"	"	12.6	"	"	"	"	"	"	"
7-in.	"	"	"	14.0	"	"	"	"	"	"	"
8-in.	"	"	"	15.0	"	"	"	"	"	"	"

Dr. Chas. E. Lucke. Another element in this safety valve question, of minor importance, perhaps, is the time element. The writer has experimented for many years with rapidly rising and rapidly falling pressures, and believes that increase in pressure in a chamber may go momentarily far beyond what a safety valve is set for. Because this excess is only momentary and measured in fractions of seconds, it should not be considered of no consequence: it is indeed of far more consequence, as a suddenly applied load cannot be resisted by the metal under stress as well as a steady load. If then by any remote series of circumstances the pressure in the boiler suddenly rises, as it may, the time element will enter in, the pressure will go higher than the safety valve is set for, before the valve opens, and will suddenly stress the entire structure. This subject should be studied experimentally, with the others involving the steady rate of steam discharge to discover if it is of any consequence in practical safety valve work. Although the writer has never seen the pressure rise in a steam boiler in this way, he believes it could so rise, producing the effects described.

Jesse M. Smith. Dr. Lucke has touched on a point which needs investigation. Another point along the same line is the danger of having a safety valve too large, particularly if it be of the "pop" kind. If a boiler be stored with water at a temperature corresponding to 150 lb. pressure, and that pressure be suddenly reduced a portion of the water will instantly flash into steam and the boiler may be greatly strained and may explode. There is danger from having a safety valve too large as well as from having it too small. Those who have had to do with the investigation of boiler explosions and particularly those being questioned with regard to them in the courts will realize the necessity for rules based upon scientific investigation and reason, instead of rules having no special reason for their existence except that they have existed for hundreds of years or more. In the courts we are questioned as to rules for safety valves which

have no reason in them, and sometimes we are brought to realize that the safety valves are not in accordance with these rules.

The court may, therefore, hold us liable for damages due to boiler explosions because our safety valves may not be in accordance with some obsolete or erroneous rule adopted by some incompetent state or municipal government.

Mr. Garland P. Robinson. The importance of a careful study of safety valves is, I think, at last fully realized. Although thousands of valves are in daily use, there has been no hitherto satisfactory rule to aid the designer or user in determining the number and size of valves required.

2 The derivation of a formula for the size of valves for stationary and marine boilers would appear to be a comparatively simple problem. Locomotive boilers, however, are operated under entirely different conditions and the determination of the proper size of valves is difficult. The problem in locomotive work appears to lie in the proportion of the maximum evaporative capacity of the boiler to be provided for. Present practice seems to show that it is necessary to provide for about 50 per cent of the maximum evaporation.

3 The commission with which I am connected has collected reliable data on about 7500 locomotive boilers, and during the past week I have calculated the valve capacity of 1000 of these boilers for the purpose of finding the average practice for safety valve equipment. The greatest variations have been noted. For instance, boilers using 180 lb. pressure with valves of $\frac{1}{16}$ in. lift have two 3 in. valves to take care of the evaporation from 1750 to 3350 sq. ft. heating surface, and again we find two $2\frac{1}{2}$ in. valves used to take care of 900 to 1900 sq. ft. heating surface. These cases represent whole classes and not individual boilers. Therefore it would appear that no rule has been followed to determine the size of valve required.

4 The function of a safety valve, as used on a steam boiler, is to discharge steam so rapidly, when the pressure within the boiler reaches a fixed limit, that no important increase of pressure can then occur, however rapidly steam may be made.

5 The heating surface, all things considered, is the best unit of measurement for determining the size of safety valves for locomotive boilers. In my opinion a formula based on the heating surface, and providing for 50 per cent of the maximum evaporation of the boiler, will give satisfactory results for locomotives. A formula for size of safety valves for locomotive boilers can be derived in the manner shown in Mr. Darling's paper on Safety Valve Capacity.

6 For locomotive valves with 45-deg. valve-seats, I would use the formula

$$D = 0.05 \frac{\text{heating surface}}{L \times P}$$

For locomotive values with flat valve-seats, I would use the formula

$$D = 0.033 \frac{\text{heating surface}}{L \times P}$$

7 I have checked 1000 boilers and find the average constant is 0.0441 for present practice. Included in the 1000 boilers, however, are a number which are evidently under-safety-valved, as the constant in their case is only 0.024. Eliminating this class of boilers, the constant for average practice is about 0.05 as given in the formula.

Mr. Wm. H. Boehm. I do not know of any boiler explosion caused by insufficient safety-valve capacity, although I have no doubt that explosions from this cause have occurred. The trouble about a boiler explosion is that after it occurs there is usually not enough of the boiler left to determine the cause of the accident.

2 I think the *time element* has a great deal to do with the safety valve question. If a safety valve is too large it may suddenly relieve so much pressure as to cause a water-hammer sufficient to produce a violent explosion of the boiler. I infer that this is the point the president had in mind when he referred to the danger of using too large a valve.

3 I believe the correct method of determining the size of a safety valve is to take into consideration the actual quantity of steam to be discharged in a given time, rather than to take the heating-surface, grate-surface, etc.

Mr. H. C. McCarty.[1] Safety Valves have passed through various stages of development by the manufacturers, although the subject is not a common one for treatment by the mechanical associations of the country.

2 Reference has been made to the difficulties or objections involved in the use of too large a safety valve. Our experience has been that a valve considered too large is one with excessive lift as compared

[1] Mr. H. C. McCarty, President Coale Muffler and Safety Valve Co., Baltimore, Md.

with the average lift of safety valves made by all reliable manufacturers.

3 Little or no specific reference has been made to the mechanical difficulties arising from valves with unusual discharge capacity produced by increased lift. In actual locomotive service we have found, that increasing the lift beyond that commonly followed as indicated by experience dangerously impairs the life and consequently the reliability of the valve, making it excessively expensive for the railroads to maintain, and unreliable and short-lived as a safety device. The hammer-blows referred to are largely the result of extraordinary lift valves, which not only cause the destruction of the valve in a comparatively short time, but are injurious to the boiler in general.

4 Railroad men in close touch with locomotive maintenance are quite familiar with the expensive renewals of cylinder heads and steam chest covers, and other associated difficulties, many of which are caused largely by water in the cylinders, and any condition contributing to this class of engine failures should be avoided.

5 Our experience has clearly proved that safety valves with *unusual discharge*, resulting from *increased lift* of valve, cause a violent disturbance in the water level, especially on the large modern locomotive boilers, and in proportion to this disturbance is the volume of water passing the throttle valve, and hence to the steam chest and cylinders, increased. Railroads will be relieved of many expensive repairs by reversing these conditions, and thus produce the driest steam possible for the engine. To this end, the throttle valve, as is well known, is located at the highest possible point in the boiler. Further to secure greater locomotive efficiency in this direction, the safety valve should be at as high a point on the boiler as clearance limits permit, and with an independent short connection of ample dimensions to the boiler.

6 Our observations have further been that the location of the valve on a boiler has much to do with the normal crest of the water. Air brake shocks in train and similar effects, in conjunction with high-lift valves, have been a frequent cause of locomotive failures through the combination of undesirable conditions, all of which cause a greater volume of water to pass through the throttle valve and safety valve.

7 In a practical study of the subject, we are confronted with these conditions that should be considered by railroad representatives in any effort to secure the greatest locomotive efficiency, with a minimum of locomotive failures and a consequent low cost of maintenance.

8 In our experience in locomotive service we have never had even a suggestion of the necessity or the advisability of increasing the lift of valve; on the contrary, the reverse condition, from a service standpoint presents itself. The possible limited economy in first cost, of a slightly smaller valve having increased lift, to accomplish increased discharge, compared with the next larger size valve with normal lift, is deceptive, as the short life and expensive maintenance of the high-lift valve make it not only an expensive burden to the railroads, but an unreliable device.

Mr. M. W. Sewall. There seems to be some misunderstanding in regard to the safety valve question, arising from following the old rules of practice without much regard to the requirements. Two items need to be considered; (*a*) how much steam will the boiler make; and (*b*) how much steam will the valve deliver. If these two requirements are adapted to each other no difficulty need arise from the use of a high lift valve. The areas of approach to the valve and discharge from it should then be such as practice has already shown to be essential.

2 The amount of steam that a boiler can make does not depend altogether on the heating surface. The most important consideration is rather the amount of coal which can be burned under the boiler, whether on a small grate or a large one, assuming, of course, that the boilers are fairly efficient.

3 The usual diameters have been mentioned in the discussion as if they could not be changed, and the high and low lifts have been spoken of as related to those diameters. As the high lift valve has a greatly increased discharge capacity, however, it should be reduced in diameter and an entirely new adaptation of diameters to "pounds of steam discharged" should be made. A manufacturer could then adopt any desired combination of diameter and lift and the valves would be rated on the pounds of steam delivered per second.

Mr. George I. Rockwood. I have been interested to hear Dr. Lucke's suggestion that he has made experiments which indicated that steam may rise in the steam boiler suddenly, without opening the safety valve, and to a point which will endanger the safety of the boiler. I think it is now obligatory upon him to state what his experiments are. There are so many boilers under steam.

2 I think we have heard something tonight that is a distinct advance in the general knowledge we have on this subject. Mr. Darling

has given us the results of a series of tests which are of considerable importance, for they show that there are no two makes of valves that have the same rise, and that they differ among themselves up to 300 per cent. Of course, they will differ enormously in their rates of steam discharge, and I think the representatives of the Casualty and Fidelity Insurance Company would be vitally interested in that.

That leads me to say that I do not understand why boiler insurance companies do not conspire together, as the ordinary fire underwriters do, and have a laboratory of their own to find out the conditions which affect the design of safety valves and devices in general that are used about the boiler plant, and then lay the law down to the several manufacturers and refuse to write insurance where those devices are not used. That is the most successful method of securing effective apparatus for fire protection, and I think it is also bound to come in steam boiler protection.

Mr. A. A. Cary. There is a saying that the recognition of a lack of knowledge is equivalent to the possession of it. This discussion has certainly done much to point out how little our stock of knowledge concerning the design and proper operation of safety valves really is. How many engineers are sufficiently posted on this subject to calculate carefully, when drawing boiler specifications, the size and number of safety valves required for the boilers they specify, and then name this carefully obtained information with the requirements of design and operation in their specifications? I am afraid there are very few, notwithstanding the great importance of this apparatus to protect their clients from disaster in their boiler-houses. I fear this information is too often obtained from the catalogues of boiler manufacturers, which may or may not be safe practice.

2 I was particularly interested in Mr. Carhart's discussion relating to safety valve springs, perhaps owing to my many years experience in the manufacture of springs, and I agree with his statements. The spring having the least amount of lift (or compression) is certainly the safest. With a spring having a greater amount of lift, you increase the bending and torsional strains in the wire, thus carrying them nearer, or perhaps beyond, their elastic limit. I have seen many springs of very poor design used in safety valves.

3 At the December 1901 meeting of the Society, I spoke of the proper proportions of springs. The pitch-diameter of a helical spring is measured from the center of the wire on one side of the coil, across its diameter to the center of the wire on the opposite side.

The ratio between this pitch-diameter of the spring and the diameter of the wire composing it should not be less than 5 to 1, but 7 to 1 is a better minimum proportion. A pop-valve spring certainly should not be wound to a smaller proportion than 7 to 1, and with such spring coiled to a smaller ratio I have found a considerable breakage resulting.

4 One matter deserving careful attention in the design of pop-valve springs is the shape of the section of wire used. Somebody's grandfather seems to have started the manufacture of these springs with wire having a square section and no one has had the courage to depart from this undesirable practice. Unquestionably, the best and safest wire for springs is that of round section. The principal stress occurring in the wire of a helical spring is that of torsion, and in a wire of square section we have the greatest fiber stress occurring at the corners of the square, which are the most distantly removed from the center of the section.

5 These corners are really the weakest part of the section owing largely to the heat treatment to which the spring is subjected. In heating the spring, prior to tempering, the corners of the square wire are the first parts of the section to become heated and are the most liable to become over-heated. When the spring is plunged into the cooling fluid, the sharp corners are chilled first, and very suddenly, and are generally found to be harder than the interior of the wire composing the spring. For these reasons, small checks or cracks are liable to be developed in these corners. Any one having had experience in tempering steel dies, rolls, etc., knows the necessity of avoiding sharp corners as starting-places for these incipient cracks which so often result in the destruction of the tempered piece.

6 These statements are not based upon theory alone as I have had ample opportunity to note the *much* larger percentage of breakage in the square than in the round-wire springs. In many cases where customers have complained of trouble from breakage, I have induced them to change from square to round wire and their troubles have ceased.

7 The only advantage gained by the use of square-wire springs is reduction of the space required for a spring having the same resistance to compression, but as the difference in space occupied is not very great, such requirements should not cause the selection of an inferior spring.

8 The most durable of all is the helical spring designed to resist extension, known as an extension spring. When this spring is prop-

erly applied, the load is carried directly along the line of the spring's axis, thus doing away with the "buckling" which so frequently imposes harmful bending strains (in addition to the torsional strain) in the wire composing compression springs. The use of compression springs for pop-valves has become almost universal, but there is no reason why extension springs of good design cannot be used for this purpose. In order to obtain a square bearing at the bottom and top of compression springs, the wire at their ends must be annealed and "hammered down" and then ground flat. After this "squaring-up" process, we frequently find a greater length of wire subjected to torsion on one side of the spring (as the spring is compressed) than on the side diametrically opposite. This frequently causes the harmful buckling and distortion of the spring, and again, the flattened spring ends, by holding the wire rigidly at both ends, cause severe additional stresses in the wire of the spring as explained in my discussion at the 1901 meeting.

9 A certain amount of lag occurs in helical springs just before they begin to compress (or extend), requiring a little greater force to operate than that for which they are adjusted. This fact doubtless contributes somewhat to the sudden "pop" when the safety valve opens; as well as the time-element referred to earlier in the discussion.

10 Every compression spring used in a pop-valve should be so constructed that its coils may be suddenly compressed "coil to coil" many times without showing signs of setting (or shortening, as Mr. Carhart has stated).

11 Great care must be taken in the use of springs applied to valves used on superheaters, to prevent their excessive heating. When the steel is heated to recalescence the spring will collapse and for this reason a pop-valve spring should never be allowed to reach a temperature above 500 deg. fahr., and 450 deg. would be a safer limit.

12 In the Cary process of tempering, invented by my father many years ago, which depended upon heating the spring first to the temperature of recalescence, I found that a straight spring could be bent to almost any odd shape before heating, and after it was raised to this recalescent temperature, it would retain the shape given to it by the former on which it was secured.

Dr. A. D. Risteen.[1] Referring to the suggestion that the different companies interested in boiler insurance—there are probably thirteen or fourteen of them in this country— coöperate to conduct an investigation for their mutual benefit, the idea seems to me a very good one, and this subject of safety valves would be an excellent one to take up. When Mr. Rockwood suggested, however, that we try to lay down the law to the manufacturers and owners of boilers, I think he named a task from which the boldest might shrink.

Mr. F. L. Du Bosque. The discussion has shown us who is responsible for the incorporation in the United States Marine Laws of a formula for deciding the size of safety valves, which has caused marine engineers considerable trouble. No formula on mechanics of any character whatever should be incorporated into a law unless the formula is complete, and without doubt should not be so incorporated when some of its factors are left to the opinion of any one of a great number of persons concerned in its use. The formula mentioned has this very serious defect and therefore should not have been incorporated into the law.

2 The factor W is made up of two quantities, the calorific value of the fuel and the amount burned per square foot of grate surface, and the value of these factors can with reasonable judgment be varied so as to vary the size of the safety valve at least 50 per cent. It is now impossible for a designer to specify the size of a safety valve on a marine boiler without first obtaining from the United States inspector his opinion on the value of these two factors, notwithstanding the fact that the inspector who is compelled to decide this question cannot possibly have as much information to assist him as the designer. On vessels licensed by our Government, that operate on long and continuous routes, the calorific value of fuel, and amount burned per square foot of grate surface, can be determined with a reasonable degree of accuracy, but these vessels are probably not more than 20 per cent of the total number of vessels to which this safety valve formula is to apply. The remaining 80 per cent burn fuel varying at times in calorific value in the ratio of one to two and their fuel consumption per square foot of grate varies in nearly as great a ratio.

3 This new formula, therefore, has not in any way improved

[1] With the Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.

the Rules of the Steamboat Inspection Service and, as pointed out above, has added only a complication. As to results produced by it, it is easy to see that by selecting proper proportions for the two factors that make up W, and these factors both may be within reasonable limits, the same result will be obtained as by the old formula. The old formula at least gave the designer a certain basis to work on, and if he was designing his work with the proper regard for safety he had the privilege of deviating from the formula if he felt it did not provide a valve of large enough size.

4 This new formula is also similar for cylindrical and water-tube boilers. Practical operation shows that a safety valve on water-tube boilers should be much smaller than on cylindrical boilers of equal evaporative power. A sudden release of steam pressure in a water-tube boiler with its limited water-line area causes more damage by lifting the water within the boiler than can be caused by a moderate increase in steam pressure.

Mr. L. D. Lovekin. In reply to the remarks by Mr. DuBosque, I was not aware of the trouble I had caused marine engineers, and still further, I see no reason for such trouble. When I design a boiler, I always state on the drawing the rate of evaporation expected and send the plan to the inspectors for approval. I have as yet to have a boiler returned by the inspector for the first time, asking for a change in the sizes of safety valves. I think the inspectors realize that the designer is the one to settle on this.

2 I have had considerable experience with the designing of boilers for different steamships throughout the United States, both for natural and for forced draft, and was therefore aware of the very crude conditions existing, relating to sizes of safety valves for such boilers as are in use by the Steamboat Inspection Service. I discussed the matter fully with a number of engineers and showed them the new formula which I proposed submitting to the Board, and all agreed that my formula was based upon common sense.

3 You all know that any safety valve based on one square inch of safety valve for three square feet of grate area for a Scotch boiler, and one square inch of safety valve for six square feet of grate area for a water-tube boiler, is absurd, and yet this was the formula used by the United States Inspectors for many years.

4 I see no reason for a jump in the size of safety valves from 4.16 to 4½ in. in diameter, as a 4¼-in. valve would answer the purpose. When the new rule was adopted, the idea was to limit the size of

safety valves to about $4\frac{1}{2}$-in. in diameter on account of the danger of using large valves, and the understanding was that if a valve came to an odd size for manufacture, we would simply take the next size larger.

5 I firmly believe that the safety valve for any boiler should be based on evaporation only, as otherwise the danger lies in the boiler generating more steam than the safety valve can carry away.

6 Mr. Nelson Foley, of England, who is quite an engineering authority, states that safety valves may be made capable of lifting say $\frac{1}{8}$ of their diameter; that a high lift is useless and may be an evil if anything gives way; that the waste steam pipe, when not under the Board of Trade, may be equal in area to the opening with the lift just mentioned, i.e., the area of the waste steam pipe would be one-half the gross cross-sectional area of the valve.

7 Our United States Navy Steam Engineering Department, with all their experience in connection with boilers, have agreed with several prominent authorities abroad on a lift of $\frac{1}{8}$ the diameter of the valve. It does not follow, however, because a valve has provision for a lift equal to $\frac{1}{8}$ of its diameter, that it ever lifts this amount. It is simply a provision in case the valve is required to be lifted by the safety valve hand-operating gear usually provided on all ships.

8 The area of waste steam pipe on all our recent naval vessels is made $\frac{1}{2}$ the gross cross-sectional area of the valve, which accords with the statements of Mr. Foley.

9 There seems to be a misconception as to what constitutes a high lift. There is probably not a safety valve manufacturer who cares to see a safety valve lift $\frac{1}{4}$ in., no matter how large the valve is, in fact, the writer's rule is based on the proportion of $\frac{1}{32}$ the diameter for the lift, and therefore becomes $\frac{1}{8}$ in. on a 4-in. valve; if worked out below a 4-in. valve, the lift becomes proportionately less, and if used for a $4\frac{1}{2}$-in. valve the lift does not become excessive under the formula.

10 It is a coincidence that while the present rule might give an excessive lift on sizes above $4\frac{1}{2}$-in. diameter, it averages up closely to the sizes recommended by many manufacturers for valves below $4\frac{1}{2}$-in. diameter. The rate of evaporation of 180 lb. in the present rule almost coincides throughout with the Board of Trade formula for safety valves under natural draft.

11 It appears therefore that the Board of Trade thought it wise to keep all boilers under natural draft at the same rate of evaporation, i.e., all boilers worked under natural draft are assumed to be

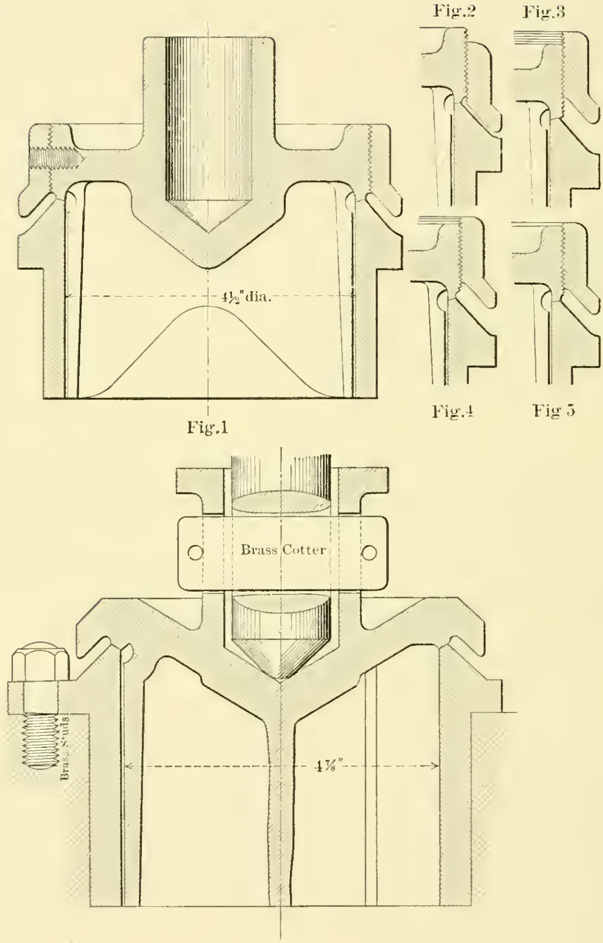


Fig. 1 Results of Experiments on Safety Valve Lips

Valves rose at 81 lb. and lifted about $\frac{3}{32}$ in. Ratio of valve area to grate area $\frac{1}{2}$ sq. in. to 1 sq. ft. Fig. 1 valve closed in $\frac{1}{2}$ min. at 79 lb., and vibrated considerably. Fig. 2 blew steadily, without closing. Fig. 3 closed in 1 min. at 80 lb. pressure dropped steadily. Fig. 4 same as in Fig. 3. Closed in $\frac{3}{4}$ min. at $79\frac{1}{2}$ lb. Less vibration than in Fig. 1.

capable of evaporating 180 lb. of water per square foot of grate surface, which seems to be a safe maximum rate for any marine boiler under natural draft.

12 When forced draft is used, under the Board of Trade regulations, the area of the safety valve must not be less than that found by the following formula:

$$A \times \left\{ \begin{array}{l} \text{estimated consumption of coal per} \\ \text{square foot of grate, in pounds per} \\ \text{hour} \div 20 \end{array} \right\} = \begin{array}{l} \text{area of valves} \\ \text{required} \end{array}$$

A equals the nominal area of the valve, based on its diameter, as found from the table of safety valve areas under the Board regulations.

13 The results of experiments on safety valve lips illustrated in the figures may be of interest to the members of the Society. These experiments were made by Mr. Nelson Foley to determine the effect of adjusting the lip on safety valves.

Mr. A. B. Carhart. Certainly there is one way in which safety valves should not be rated, and that is by the area of the disc or of the inlet connection; for in every case the outlet discharge capacity is proportional to the circumference of the valve seat, and the circumference will of course increase in proportion to the diameter, while the inlet and disc areas will increase in proportion to the square of the diameter. If the lift of the disc is the same for all the ordinary sizes of valves, the discharge areas and capacities of the valves are directly proportional to the diameters, and the inlet diameter size becomes a direct measure of the relative size or capacity of the valve. There seems to be no good reason to depart from this method of denoting valve sizes, which has been the uniform custom in the past and will be found more accurate than any other method.

2 The lift may properly be assumed to be uniform in all sizes of valves such as we are considering, for this is the actual performance in practice. Any measurable difference in special cases will generally be found due to the larger valves lifting less vertically than the smaller as is proper in the interests of prompt and quiet action, durability of the valve and safety to the boiler. The smaller valves have less weight of moving parts, less momentum, less load, and springs of more tractable proportions, and may safely lift higher.

3 Neither should valves be rated in discharge area alone. The discharge rating would be different for every pressure and dependent

upon the care in maintaining the uniformity of commercial springs; and in any case would be a theoretical amount arrived at by a formula which might be amended by any designer or salesman to suit the exigencies of contract price or capacity specification. This would introduce a hopeless confusion in odd sizes, besides leaving the engineer at the mercy of the representations or the misrepresentations of selling arguments.

4 The standard sizes, familiar to all engineers, now denote the size of the inlet pipe connection which must be provided in the boiler. For different designs of valves, having different apparent or claimed efficiencies, allowance can be made in the judgment of the engineer. We do not rate iron pipe by discharge capacity or area, but by commercial diameter sizes, and this custom has never been overturned at anyone's suggestion merely because the inside diameter of hydraulic or extra heavy or brass pipe differs from that of ordinary pipe, or because bends and elbows may reduce the flow; engineers exercise their judgment in specification, and this is their proper function and province.

5 The actual lift or discharge areas of valves should be determined and reported upon after impartial tests conducted by competent and disinterested engineers under conditions of scientific accuracy and with due precautions, where each valve is intelligently regulated to work to the limits normally intended; and not from reports of tests conducted by any one manufacturer without the knowledge of other makers whose valves are tested, and where the one measurement noted has been in many cases purposely limited by the manufacturer for special reasons.

6 In rating a valve by its diameter, we use the small diameter of the seat, measuring the area open to the steam pressure when the valve is closed. The seat is made on a comparatively narrow face, preferably not more than $\frac{3}{32}$ in. broad. The line of steam-tight contact is a variable or wavy line, which can be detected by rubbing the beveled face of the valve seat with blue chalk and grinding the disc on it. In no case is it mathematically measured by the inlet diameter; it is always a fractional percentage greater than that, but the difference is ordinarily neglected, and is very small. In very accurate work the mean between the inside and outside diameter would be more nearly correct, but in all commercial ratings, the nominal diameter of the throat is taken.

7 The actual area is determined by experiment and by allowances arrived at by experience. That is, a new valve might have the seat

near the inside and an old one at the outside edge of the seat face, and when it is properly drawn it will be seated either one way or the other. But this would not affect the calculation of the amount of steam that would flow through the valve opening, for that is determined by the circumference of the inner edge of the seat face, where the flow of steam comes up through the throat of the valve and turns outward over the edge of the seat. This sinuous line of contact on the seat face when the valve is closed would affect only the total spring load required or the pressure upon the disc by the confined steam when the valve is closed, because of the slightly varying area open to the steam; but I believe this does not affect the rate of flow or the amount of the opening, as soon as the valve lifts.

Mr. Nathan B. Payne. The most important point brought out by this discussion is that there is no proper standard of measurement for the safety valve's capacity. Whether we take a high-lift or a low-lift valve, what we must have is some way of measuring what relieving capacity we are getting. When we buy a 4-in. valve, for instance, we want to know whether that valve has relieving capacity for a 100-h.p. or a 200-h.p. boiler, or what size it is suited for. Here is a magnificent opportunity for this Research Committee to take up this subject and adopt some standard method of determining the capacity of safety valves.

2 We have been going ahead thinking we were right on the relieving capacity of safety valves when considering only one dimension, but it is absolutely impossible to determine the amount of relieving capacity in a given time without knowing the lift of the valve off the seat, so as to get the effective area of opening. The question for the user to decide is how much relief he can get from a given make and size of valve. If one maker offers a safety valve having $\frac{1}{32}$ in. lift, and another offers a $\frac{1}{8}$-in. lift, each should state how many pounds of steam per hour his valve will relieve.

Mr. Frank Creelman. I wish to speak regarding Mr. Rockwood's question, as to the insurance companies taking up the matter of the safety valve. The earliest experiments on the safety of parts of the boiler were made for the Manchester Union Steam Users' Association by Sir William Fairbairn, on the strength of boiler flues to resist collapse. This Association's engineers up to this day have continued to carry on original experimental work relating to the safety of boilers.

Mr. Boehm. In speaking earlier of the danger of having too large a valve, and the water-hammer it might cause, the writer had in mind, not too large a diameter but a valve of too large capacity. A small valve with a high lift, if the full effect of that lift suddenly be obtained, might discharge as much steam in the same length of time as a large valve with a low lift. The *time element* was the thing I particularly wanted to mention.

2 Mr. Rockwood had something to say regarding the writer's statement that he had known of no boiler explosion caused by too small a safety valve. The writer did not mean to say that no boiler had exploded for that reason, but that he did not *know* of one. He does know of cases where slice bars and other things were hung on the safety valve lever, of cases where stop valves had been placed between the safety valve and the boiler, and of one case in particular where an engineer (?) in New York had wedged a piece of scantling between the joist and the top of the safety valve lever.

Mr. Pond. The paper read by Mr. Darling is particularly interesting as indicating what has already been done in the direction of obtaining reliable data relative to the operation of safety valves, from test.

2 I agree with Mr. Ashton that the lift of the valve is not the essential thing. The thing to be determined is how much steam a given valve will discharge under any given set of conditions. That particular piece of information is the one that none of the valve manufacturers have been able or willing to give us, as none of them have previously made the tests necessary to determine these points. This information relative to valve capacity is what I have been trying to get and I have every reason to believe that very shortly we will have presented results of a number of tests bearing on this subject. Tests are being conducted and being prepared for at the present time, from the data of which we may hope to determine more accurately the correct proportions of safety valves for a given service.

3 This question of high-lift and low-lift valves seems to me to be one simply of capacity. If the low-lift valve will deliver a certain number of pounds of steam at a given pressure and temperature, and we know what its capacity is under these conditions, this is the principal thing required. The same test applies in the case of the high-lift valve, the essential point, however, being to know how much steam the valve will discharge. Undoubtedly a high-lift valve will give more capacity than a low-lift valve having the same diameter of open-

ing. This being so, we could use a smaller valve of the high-lift type on a boiler, than of the low-lift type, which would be an advantage in many ways.

4 I trust that before this subject is left steps may be taken by the Society to take definite action on the formulating, or rather revising, of the safety valve rules for stationary, locomotive, and marine practice, standardizing them on the basis of the capacities of the valves.

5 The first step is to get the manufacturers or some disinterested parties to make quantitative tests which will give us an accurate measure of how much steam can be discharged through a safety valve.

MISCELLANEOUS DISCUSSION

LIQUID TACHOMETERS

By Amasa Trowbridge, Published in The Journal for Mid-October

The Author. Mr. Moss is correct in his statement regarding the accuracy of a liquid tachometer. The general impression seems to be that the instrument wears in such a way as to effect its readings. Such is not the case. Any leak caused by wear would render the instrument inaccurate until the leak was stopped, but as soon as this trouble was remedied the instrument would again be accurate without being recalibrated.

2 In regard to building an instrument with a vertical driving-shaft, this is a perfectly feasible proposition. The opening for the shaft would have to be kept above the zero level of the instrument to avoid the necessity of a stuffing-box. If this were done, wear would not make the instrument leak. It is probable that an instrument of this form will be put on the market as soon as there is sufficient demand for it.

3 In most cases the instruments are not used for continuous running, but are applied to continuous running machines in such a way that they can be thrown into or out of engagement at will, and the speeds are usually indicated only at stated intervals. In this way the wear on the instrument is slight and trouble is not experienced from leaking through the stuffing-box.

THE TOTAL HEAT OF SATURATED STEAM

By Dr. Harvey N. Davis, Published in The Journal for November

The Author. The first seven paragraphs of Professor Thomas' discussion are a valuable contribution to the outstanding C_p controversy, especially his statement that according to his new experiments, "there is no question that a comparatively very large amount of heat is required to cause a very small rise of temperature of dry saturated steam." The publication of these new results will be eagerly awaited by all interested in the subject. In the meantime, it should be remembered that this C_p controversy has much less to do with the

validity of the results in this paper than might at first be supposed. As has already been pointed out in Par. 3 of my closure, the use of Professor Thomas' values of C_p instead of Professor Knoblauch's would make only a small difference in H. It is interesting to notice that the changed values of H would be even farther from Regnault's than are those proposed in this paper.

2 The last three paragraphs of the discussion raise a much more vital question as to the validity of the throttling experiments on which this paper is based. This criticism has also been made by Professor Heck. It is true that throttling experiments have fallen into disrepute "in view of the well-known troubles that have been experienced" in "two lines of experimental work," namely in determining the quality of wet steam and in computing C_p from H. Of these, the latter is a use for which such experiments are particularly ill-adapted, and it is this very fact which makes the reversal of the process—the computation of H from C_p—so insensitive to errors in C_p. As to the former, one should remember that the ordinary throttling calorimeter, even when "great care is employed as to lagging, position, etc.," is the crudest sort of an instrument of precision, as far as heat insulation and the measurement of the low-side temperature are concerned, so that it is not remarkable that great accuracy is not attained.

3 The experimenters whose results are the basis of this paper used apparatus of a very different sort. Their three different systems of heat-insulation and of thermometry, although by no means perfect, were much better than those of which the average engineer would be reminded by Professor Thomas' allusions to throttling calorimetry. If the precautions of any one of them had not been effective, no such agreement of results based on their work could possibly have been expected as is actually found. The value of their mutual corroboration, in every respect that concerns this paper, is increased by the fact that both Griessmann and Peake were primarily interested in disproving a certain conclusion of Grindley's, so that their critical attitude might have been counted on to ensure substantial improvements in Grindley's results, if that had been possible. If this paper had been founded on Grindley's work alone, the doubts of Professors Thomas and Heck would have had great weight; but the fact that all three pieces of work were used, *and the results agreed*, is good evidence that these throttling experiments are beyond the uncertain and inconsistent stage which Professor Thomas describes.

Prof. Carl C. Thomas. The discussion during the past few months regarding the properties of superheated steam, and also that which now bids fair to throw additional light upon the total heat of saturated steam, has been exceedingly valuable. The discussion has involved the work of a number of experimenters, and a few points concerning the results of some of the experiments ought to be emphasized lest they be lost sight of or misunderstood. Also, the writer wishes to make a suggestion regarding the proposed revision of the steam tables upon the basis of throttling calorimeter experiments.

2 Knoblauch's experiments begin at about 30 to 50 deg. fahr. superheat for each of the four pressures used; the writer's begin at 18 deg. fahr. superheat for all the pressures used Knoblauch's upper limit of temperature varies from about 325 to 400 deg. fahr. superheat, while the writer's experiments stop, in all cases, at 270 deg. fahr. superheat. In that part of the temperature range which is common to both sets of experiments, namely, between 30 or 50 deg. fahr. and 270 deg. fahr. superheat, the results in the two cases are almost identical. The greatest variation appears at about 28 lb. absolute pressure and 54 deg. fahr. superheat where Knoblauch obtains $C_p = 0.478$ and the writer obtains 0.498. The writer's experiments from 18 to 50 deg. fahr. superheat show higher values of C_p than are shown by the extrapolated curves of Knoblauch.

3 Knoblauch worked at absolute pressures of about 28 lb. to 114 lb. while the writer worked at absolute pressures from 7 lb. to 500 lb. Knoblauch obtained his saturation curve by extrapolation from experimental determinations at about 30 or 50 deg. fahr. superheat, while the writer obtained his saturation curve by extrapolation from exper ments made at 18 deg. fahr. superheat. The two curves show widely different values for C_p at saturation, the writer's being much higher than Knoblauch's.

4 In view of the very close agreement in values of C_p from 50 to 270 deg. fahr. superheat, obtained in these two sets of experiments made by entirely different methods, it seems safe to accept either set of these values as substantially correct for this temperature range.

5 Correspondence which has passed between Professors Schröter and Knoblauch and the writer brings out the fact that the former are pushing their experiments into the higher temperature ranges, desiring to corroborate and extend their already published results, which show a minimum value of C_p somewhere in the neighborhood of 230 deg. fahr. superheat for each pressure, followed by an increase of

C_p after the region of minimum value has been passed. Their method and apparatus are especially well adapted to experimenting with highly superheated steam. On the other hand, the writer is working back towards the saturation condition, with an apparatus which has been planned with the special end in view of definitely locating the saturation curve. Appreciation of the real difficulties in obtaining exact knowledge as to moisture conditions existing in steam can be attained only by those who have made actual and extensive experiments.

6 The writer's experiments have led him to expect to find a saturation line, and not a "saturated region." Upon this assumption, such curves as are shown in the writer's Fig. 13 should, as shown, pass through the intersection of the coördinates, namely, heat introduced per unit weight of steam, and temperature to which the steam is being superheated. It is with the determination of the form of these curves, near the intersection of the coördinates, that the writer is now engaged. There is no question that a comparatively very large amount of heat is required to cause a very small rise of temperature of dry saturated steam, which means that C_p is comparatively large in value right at saturation. The writer is attempting to ascertain, by the use of very sensitive resistance thermometers instead of the thermo-couples formerly used, whether it is a case of "jogging the steam out of the saturation region," as some writers have suggested, by the introduction of a considerable amount of heat—or whether any small increment of heat will cause a correspondingly very small rise of temperature of steam which has just reached the condition of complete dryness.

7 In the absence of further data at present which would tend to establish the relative correctness of Knoblauch's and the writer's saturation curves, it is interesting to notice that curves can be drawn through Knoblauch's points as given in his Fig. 12 which will produce the writer's guess at the saturation curve, quite as readily as the one Dr. Knoblauch has made. And, on the other hand, it would be quite possible to use the writer's data as an argument in favor of the accuracy of Knoblauch's curve. However, the writer has some confidence in the general reliability of his curve, because it is based upon experiments extending down to within 18 deg. fahr. of the saturation temperature, while Knoblauch stopped his experiments at a considerably higher temperature. The fact that the two sets of results agree so well, within the temperature-range actually covered in common by the two sets of experiments, affords evidence of the reliability of the values

given for C_p; and the further consideration that each of the writer's experiments started with a determination of the saturation point as its basis, and from that went up and fairly met Dr. Knoblauch's results, which were obtained without reference to the saturation point, gives reason for accepting with some confidence the saturation curve marked out by the writer's experiments. However, it will be apparent from the above remarks that the writer is going over this whole question of the saturation line again in the experiments now in progress.

8 The reason why it is worth while to go carefully into this matter is apparent, and is especially cogent at the present time from the standpoint of the engineer as well as the physicist, because of the interesting suggestion of Dr. Davis that the steam tables based on Regnault's classic experiments be revised on the basis of experiments which have been made on the expansion of steam in throttling calorimeters, or through porous plugs, for the purpose of determining the specific heat of superheated steam.

9 It is not the writer's intention or desire to detract from the interest attaching to Dr. Davis' proposed use of throttling experiments for indicating the extent to which Regnault's values of total heat of saturated steam should be changed. The indications obtained from the throttling experiments will undoubtedly be suggestive and possibly conclusive, but they should not be accepted, without experimental corroboration, as a basis for a revision of the steam tables. During the past eighteen years, to the writer's knowledge, experiments have been made with the object of obtaining values of C_p by throttling steam. The results ha e never been consistent among themselves, nor have they given values for C_p comparable with those which have been made by the direct means of electrical heating of the steam. For a time some of the throttling experiments were accepted by engineers, and it was then thought that the specific heat of superheated steam was very much higher than it has since been shown to be, the errors in the throttling method all tending to increase the apparent value of C_p.

10 Useful as the throttling calorimeter is, it is not necessary to remind engineers of the very great difficulty of obtaining reliable or at all consistent results as to quality of steam, by its use, no matter how great care is employed as to lagging, position, etc. It may be a question of uniformity of steam conditions at inlet to the instrument, or in the instrument itself at the point where the temperature is taken. The writer is aware that the method by which Dr. Davis

proposes to use the results of calorimeter experiments does not involve precisely the same considerations as those involved in determining the quality of steam, or in fact of determining the specific heat of steam by the throttling method. But in view of the well-known troubles that have been experienced in these two lines of experimental work, it seems decidedly inadvisable to base such an important matter as a revision of the steam tables upon experiments in throttling steam, without thorough corroboration by direct measurement.

11 The direct measurement of the total heat of dry steam will be possible of attainment with great accuracy as soon as the saturation line above referred to, and the heat necessary to raise the temperature of unit weight of steam some distance above saturation, have been definitely and finally determined. Means of applying heat electrically, in absolutely measurable quantity sufficient not only to evaporate water into dry steam but to superheat the steam by some known amount, afford means of direct measurement of the total heat of dry steam, because the heat applied above that necessary to obtain the saturation condition will be known, as soon as the saturation curve has been determined, and this superheat can be subtracted, leaving as a remainder the total heat of dry saturated steam.

12 The writer would not wish it understood that he urges delay in revising the steam tables until his own experiments shall have been completed. That is not at all the point. By the time the saturation curve is definitely located, and possibly before, the writer will be glad to turn the work over to anyone else who may be in position to go on with it; or the desired results may be obtained by some other experimenter entirely independently and before the writer's experiments can be brought to a satisfactory conclusion; but since methods of direct electrical measurement are now available and admirably adapted to this purpose, such means should certainly be used as a check upon the accuracy of the methods proposed by Dr. Davis, before engineers are asked to accept a new set of steam tables. Otherwise we shall have just such a condition of uncertainty regarding the accuracy of our steam tables as has existed for many years with regard to the specific heat of superheated steam.

ACCESSIONS TO THE LIBRARY

BOOKS

Annual Report of the Boston Transit Commission. 14th. *Boston, E. W. Doyle, 1909.* Gift.

Annual Report of the Light-House Board to the Secretary of Commerce and Labor, June 30, 1908. *Washington, Government, 1908.* Gift.

Annual Report of the New York State Museum. 61st. Vol. 1 and 3. *Albany, University of the State of New York, 1908.* Gift.

Bulletin of Syracuse University. Series 8, no. 4. *Syracuse, 1909.* Gift.

Cassier's Magazine. Vol. 1, 1891–1892. *New York, 1892.* Gift of H. H. Suplee.

Cuyahoga Valley Viaduct of the "Nickel Plate" Railroad. Read at the Meeting of the Cleveland Engineering Society, October 13, 1908. By G. H. Tinker. *Cleveland, 1908.* Gift of Cleveland Engineering Society.

Development of the Electric Piano Player. By J. F. Kelly. Reprinted from Journal of the Franklin Institute, *Jan., 1909.* Gift of author.

Engineering Magazine. Vol. 1, no. 5 and 6; vol. 2, no. 1 and 2. *Aug.–Nov., 1891.* Gift of H. H. Suplee.

Flight Velocity. By A. Samuelson. *London, Spon, 1906.* Purchase. $0.75.

Flying Machines: Past, Present and Future. By A. W. Marshall and Henry Greenly. *London, P. Marshall & Co.* Purchase. $0.40.

Gas Engineer's Laboratory Handbook. 2d edition. By John Hornby. *New York, Spon & Chamberlain, 1902.* Purchase. $2.

Hobart College Bulletin. President's Report, 1908–1909. *Geneva, N. Y., College, 1909.* Gift.

Mercurial Air Pump, The. By Prof. Silvanus P. Thompson. (Reprint with additions from the Journal of the Society of Arts.) *London, E. & F. N. Spon, 1888.* Purchase. $0.60.

Modern Foundry Practice. 2d edition. By John Sharp *New York, Spon & Chamberlain, 1905.* Purchase. $8.

Portland Cement: its Manufacture, Testing and Use. 2d edition. By D. B. Butler. *New York, Spon & Chamberlain, 1905.* Purchase. $5.

Portrait of Frederic A. C. Perrine, with a few words regarding his life and work. *1908.* Gift of F. V. T. Lee.

Proceedings of the 18th Annual Convention of the American Railway and Building Association, Washington, Oct. 20–22, 1908. *Concord, N. H., Rumford Printing Co., 1908.* Gift.

Proceedings of the Incorporated Institution of Automobile Engineers for 1906–1907. *London, 1907.* Exchange.

Report on the Kanowna Mines. By A. Montgomery. *Perth, 1908.* Gift of Western Australia Department of Mines.

Report on the Northampton Mineral Field. By A. Montgomery. *Perth, 1908.* Gift of Western Australia Department of Mines.

Resistance of Air and the Question of Flying. By A. Samuelson. *London, Spon, 1905.* Purchase. $0.75.

Sächsischer Dampskesse Revisions Verein, Chemnitz. Ingenieur-Bericht, 1908. *Chemnitz, W. Adam, 1908.* Gift.

Steamship Coefficients, Speeds and Powers. By C. F. A. Fyfe. *New York, Spon & Chamberlain, 1907.* Purchase. $4.

Die Turbine. Zeitschrift für Moderne Schnellbetrieb für Damp-Gas Wind and Wasserturbinen. Organ der Turbinentechnischen Gesellschaft. Semi-weekly. Vol. 1–4. *Berlin, M. Krayn, 1904–1907.* Gift of Prof. Edward C. Schmidt.

Washing and Coking Tests of Coal at the Fuel-Testing Plant. Denver, Colo., July 1, 1907–June 30, 1908. By A. W. Belden, C. R. Delamater, and J. W. Groves. *Washington, Government, 1909.* (U. S. Geol. Survey. Bulletin no. 368.) Gift.

CATALOGUES

American Iron and Steel Manufacturing Company, *Lebanon, Pa.* Boiler Rivets.

Catalogue of Manufactures. *1908.* Refined bar iron, bolts, nuts, rivets, spikes, and forgings for railroad telegraph and telephone work.

Crane Company, *Chicago, Ill., 1908.* Effect of Superheated Steam on Valves and Fittings.

Eck Dynamo and Motor Company, *Belleville, N. J.* Sectional Catalogue and Data Book. (Bulletin no. 39.)

Greene, Tweed and Company, *109 Duane St., New York, 1908.* Belt studs, hooks, tools, clamps, etc.

National Electric Lamp Association. Tungsten Multiple Lamps. (Bulletin no. 6D.)

NILES-BEMENT-POND COMPANY, *Cincinnati, O.* Reprints regarding cutter grinders.

SCHUTTE AND KOERTING COMPANY, *Philadelphia, and 50 Church St., New York.* Apparatus for: Feeding boilers; Lifting liquids; Heating liquids; Moving air and gases; Atomizing liquids; Valves; Condensers; Hydraulic machinery; Sulphur furnace plants for sulphuric acid manufacturing. Subject index; code words of sizes in inches.

STEAM POWER CENTRAL STATION, A MODERN. Designed and Installed by Charles C. Moore & Co., *San Francisco, Cal.*

H. N. STRAIT MANUFACTURING COMPANY, THE. *Kansas City, Kan.* Scales, cooperage machinery, friction clutches, transmission and conveying machinery, etc.

HUBERT H. WARD AND ASSOCIATES, *Cleveland, O.* The Seaton Spring Wheel.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

055. Wanted: an assistant superintendent in factory manufacturing a line requiring a large production of small duplicate parts. A man with experience in clock, lock or typewriter factory, with technical training preferred. Applicant must have held executive positions. Location Pennsylvania.

056. A man with shop experience, capable of selling high-grade machine tools wanted, in the middle West. Technical graduate preferred.

057. Designing draftsman and detailers wanted by steel company. Location Pennsylvania.

MEN AVAILABLE

231 Mechanical and Structural Engineer, with business training, going to Europe this summer, would like to act as representative for responsible concern expecting to introduce their goods abroad.

232 Member, 20 years experience with large companies, in design, manufacture and operation of steam, electric and gas machinery, accustomed to handling men and conducting correspondence, desires to get into communication with concern with view to engagement as Assistant Chief Engineer or Chief Draftsman. Best of reference.

233 Junior, technical graduate, going abroad again this June, would like to make the acquaintance of parties having European connections with view to temporary engagement.

234 Member, Stevens graduate, desires to make a change. Competent as Manager, Superintendent or Chief Engineer. Fifteen years experience in machine tools, hydraulic machinery, coal and gas fired furnaces, conveying machinery and plant equipment.

235 Mechanical Engineer, 35 years of age, with practical shop and technical experience in design and construction of special and automatic machinery, manufacturers' tools, for speedy and economical production of interchangeable parts;

thoroughly familiar with best up-to-date shop practice and management, costs and efficiency, good organizer and systematizer with excellent executive ability, and can produce results, desires to locate permanently with concern in vicinity of New York.

236 Superintendent desires position, preferably in manufacturing plant with machine shop and foundry producing medium weight machinery.

237 Member with long experience in design of material-handling machinery, including elevators, conveyors, coal tipples and screens, crushing and concentrating plants, also steel and timber mill buildings, desires to become connected with some responsible concern where his special training will be of value.

238 Junior Member, B.S. and M.E., experienced in marine engineering as draftsman and inspecting draftsman, and in the installation of machinery in battleships and armored cruisers; was evening instructor in steam engineering five years, including laboratory work; at present in charge of a marine engine drawing room; desires position with consulting engineer engaged in power station work or with engineering building company.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALEXANDER, Chas. A. (1899; 1905), Engr. and Contr., Builders' Exchange, and 3 Cornell St., Rochester, N. Y.

AUE, Jos. E. (1899), Pacific Gas and Elec. Co., Bayshore Dist., San Francisco, Cal.

BARNES, Charles B. (1905: 1908), Mech. Engr., Holabird & Riche, Architects, 1618 Monadnock Bldg., and *for mail,* 325 E. 53d St., Chicago, Ill.

BAUSH, George Henry (1905), M. E. and Genl. Sales Mgr., Fay Mch. Tool Co., and *for mail,* 2101 Spring Garden St., Philadelphia, Pa.

BERNHARD, Richard (Junior, 1901), Ch. Engr., Mining, Crushing and Cement Mchy. Dept., Power and Mining Mchy. Co., Cudahy, and *for mail,* 632 Wentworth Ave., Milwaukee, Wis.

BURTON, J. Harry (Junior, 1906), 1001 W. 71st St., Chicago, Ill.

COES, Harold V. O. (Junior, 1907), Liquid Carbonic Co., Michigan Ave., Chicago, Ill.

COFFIN, Frank M. (1907), Supt. of Constr. and Repairs, The Maintenance Co., 54–56 Franklin St., and *for mail,* 272 Manhattan Ave., New York, N. Y.

COFFIN, Wm. Carey (1894), Structural Engr., Jones & Laughlin Steel Co., and *for mail,* 5930 Howe St., Pittsburg, Pa.

COLE, Cyrus L. (Junior, 1908), Allis-Chalmers Co., and *for mail,* 2010 Kenmore Ave., Chicago, Ill.

CRANSTON, Raymond E. (Junior, 1907), Asst. Engr., 815 Banigan Bldg., Providence, and 31 Lawn Ave., Pawtucket, R. I.

FERRIER, Walter (1908), Carnegie Steel Co., Schoen Steel Wheel Plant, McKees Rock, Pa.

FILLINGHAM, Myles Percy (1908), Cons. and Contr. Engr., Hudson Terminal Bldg., 50 Church St., New York, N. Y.

FREDERICK, Floyd Willis (1907), Mech. Engr., Natl. Board of Fire Underwriters, and *for mail,* 235 Valley Ave., Easton, Pa.

FUCHS, Hugo (Associate, 1907), Cons. Engr., V. Lipot Blvd., 27, Budapest Hungary.

GILMAN, Francis L. (1908), Shop Supt., Western Elec. Co., 463 West St., New York, N. Y., and *for mail,* 49 Christopher St., Montclair, N. J.

GWILLIAM, Geo. T. (1891), C. E., Resident Mgr., The Hess-Bright Mfg. Co., 1974 Broadway, New York, N. Y., and The Union League, Philadelphia, Pa.

HARDING, Adalbert (Junior, 1898), The Wickes Boiler Co., Room 1411, 90 West St., and 69 W. 49th St., New York, N. Y.

HART, Rogers Bonnell (Associate, 1907), Ch. Draftsman, Pittsburg Gage and Supply Co., 30th and Liberty Sts., and *for mail,* 705 College Ave., Pittsburg, Pa.

HENES, Louis G. (Junior, 1903), Ry., Industrial and Contractors' Equipment, Room 731, Monadnock Bldg., San Francisco, and Key Route Hotel, Oakland, Cal.

HERR, Herbert T. (1907), Genl. Mgr., Westinghouse Mch. Co., East Pittsburg, Pa.

HILL, Reuben (1908), Factory Mgr., Bristol Engrg. Corp., Bristol, Conn.

HOLLOWAY, Thurman Welford (Junior, 1906), Asst. Prin., School of Mech. Engrg., Internatl. Correspondence Schools, and 1642 Madison Ave., Scranton, Pa.

KENT, William (1880), Manager, 1885–1888; V. P. 1888–1890; Cons. Engr., Sandusky, O.

LANE, Henry Marquette (1900), Editor, Castings and Wood Craft, Caxton Bldg., and *for mail,* 15 The Melrose, 1924 Prospect Ave., Cleveland, O.

LAWRENCE, Howard F. (Junior, 1908), Am. Soc. Mech. Engrs., 29 West 39th St., New York, N. Y.

LOGAN, Wm. J. (1880), Life Member; Logan Iron Wks., Commercial and Clay Sts., Brooklyn, N. Y.

LORD, John E. (1904), Asst. Mgr., Sight Feed Oil Pump Co., and *for mail,* 902 Richards St., Milwaukee, Wis.

MASURY, Alfred Fellows (Junior, 1904), Mech. Engr., Hewitt Motor-Truck Co., and *for mail,* 44 W. 25th St. New York, N. Y.

MICHEL, Arthur Eugene (1906; Associate, 1908), Adv. Engr., 1572 Hudson Terminal Bldg., New York, N. Y.

MILLS, Edmund (1903), 319 Arlington Ave., Jersey City, N. J.

MOLÉ, Harvey E. (1901), Lenz & Molé, 71 Broadway, New York, N. Y.

MORA, Rafael de la (Junior, 1897), Mech. and Hyd. Engr., Hidalgo 654, Guadalajara, Mex.

MURRAY, George R. (1903), Pres., The Maxwell Rolf Stone Co., 586 The Arcade, Cleveland, O., and *for mail,* 129 Pearson Drive, Asheville, N. C.

NEELY, Frank H. (Junior, 1908), Industrial Engr., 70 Madison Ave., Atlanta, Ga.

NORBOM, John O. (1900), Alta Vista Apts., Berkeley, Cal.

PAINE, Henry E. (Junior, 1906), 505 Homer Ave., Palo Alto, Cal.

PARSONS, William N. (1901), 216 Falconer St., North Tonawanda, N. Y.

PRINCE, Walter F. (1905), Supt. Fdy. Dept., Henry R. Worthington, Harrison, and 1365 North Ave., Elizabeth, N. J.

RATHBUN, Edward (1908), 2d V. P., Rathbun-Jones Engrg. Co., Spencer St., Toledo, O.

REDWOOD, Iltyd I. (1890; 1903), Genl. Wks. Mgr., Borax Consolidated (Ltd.), 16 Eastcheap, London, E. C., and *for mail,* 21 Erith Road, Belvedere, Kent, England.

RUST, William F. (1904), Youngstown Sheet and Tube Co., Youngstown, O.

SALMON, Frederick W. (1900–1904), Civil and Mech. Engr., Murray Iron Wks., and *for mail,* 815 N. 6th St., Burlington, Ia.

SHELDON, Samuel B. (Junior, 1900), Genl. Supt., Saucon Dept., Bethlehem Steel Co., S. Bethlehem, Pa.

SHIRLEY, Robert (1906), Mech. Engr., The Pratt & Cady Co., and *for mail,* 26 Lenox St., Hartford, Conn.

SINCLAIR, Angus (1883), Editor and Publisher, 114 Liberty St., New York, N. Y., and *for mail,* 400 Clinton Ave., Newark, N. J.

SMITH, S. H. (Associate, 1907), Supt., North Melbourne Elec. Tramways and Lighting Co., Ltd., Mt. Alexander Road, Ascot Vale, and Clydehall, Harding & East Sts., Melbourne, Australia.

SMITH, William E. (Junior, 1908), Mech. Engrg. Dept., D. L. & W. R. R., and *for mail*, 518 Olive St., Scranton, Pa.

SPURLING, O. C. (1907), Plant Engr., Western Elec. Co., Hawthorne, Ill.

STRAW, Charles A. (1896; 1904), Sales Mgr., Lehigh Coal and Navigation Co., and *for mail*, Lansford, Pa.

STUCKI, Arnold (1907), Engr., Farmers Bank Bldg., and *for mail*, 105 Falk Ave., N. S., Pittsburg, Pa.

SZE, S. C. Thomas (Junior 1905), Imperial Railways of North China, Tongshau, China.

TALCOTT, Robert Barnard (1907), Asst. Ch. Mech. and Elec. Engr., Office of Supervising Arch., Treasury Dept., and *for mail*, Florence Court, Washington, D. C.

THULLEN, L. H. (1905), Mech. and Elec. Engr., 540 W. 143d St., New York, N. Y.

VAN DEINSE, A. F. (Junior, 1905), El Tiro Copper Co., El Tiro, Pima Co., Ariz.

WEST, Arthur (1902), Mgr. Power Dept., Bethlehem Steel Co., S. Bethlehem, and 114 S. High St., Bethlehem, Pa.

WHEELER, Wm. Trimble (1905), Genl. Mgr., Trinity Engrg. Co., 90 West St., and 340 W. 21st St., New York, N. Y.

WHITE, John Culberton (Junior, 1906), Cons. Steam Engr., 745 E. Johnson St., Madison, Wis.

WHITTED, Thomas B. (1900; Associate, 1903), Pres., Thomas B. Whitted & Co., Contr. Engrs., Piedmont Bldg., and 317 W. 5th St., Charlotte, N. C.

WINTER, Oscar (1906), 1360 W. 112th St., Cleveland, O.

NEW MEMBERS

BRONSON, Edward L. (Associate, 1908), M. M., The Shoe Hardware Co., and *for mail*, Montgomery St., Waterbury, Conn.

DUNLAP, Thaddeus C. (1908), V. P. and Genl. Mgr., Columbus Pneumatic Tool Co., Columbus, O.

FARRELL, Harry C. (1908), Mech. Engr., United Shoe Mchy. Co., Beverly, and *for mail*, 47 Grant Road, Swampscott, Mass.

GORE, Warren W. (1908), V. P., Gas Power Mfg. Co., Seattle, and *for mail*, 1610 Main St., Olympia, Washington.

HARVEY, Minor (1908), Engr., Morse, Williams & Co., and *for mail*, 4217 Haverford Ave., Philadelphia, Pa.

HOLMES, Joseph Austin (1908), Expert in Charge Technologic Branch, U. S. Geological Survey, Washington, D. C.

HOWARTH, Harry A. S. (1908), P. O. Box 174, S. Bethlehem, Pa.

KEMBLE, Parker H. (1908), Bristol, Conn.

MONKS, Wm. Douglas (Junior, 1908), 353 S. 3d Ave., Mt. Vernon, N. Y.

SHODRON, John Geo. (Junior, 1908), 220 Burrell St., Milwaukee, Wis.

STAUBE, Edwin G. (Junior, 1908), Pres. and Managing Dir., E. G. Staube Mfg. Co., 526 S. 5th St., Minneapolis, Minn.

PROMOTIONS

WOODWELL, Julian E. (1900, 1908), Cons. Engr., Terminal Bldg., Park Ave. and 41st St., New York, N. Y.

DEATHS

REYNOLDS, Edwin.

BOYER, Francis H.

GAS POWER SECTION

CHANGES OF ADDRESS

AUE, Jos. E. (1908), Pacific Gas and Electric Co., Bayshore Dist., San Francisco, Cal.

COES, Harold V. O. (1908), Liquid Carbonic Co., Michigan Ave., Chicago, Ill.

THULLEN, L. H. (1908), Mech. and Elec. Engr., 540 W. 143d St., New York, N. Y.

NEW MEMBERS

AMSLER, W. O. (1909), Engr., 627 Wabash Bldg., and 5510 Margaretta St., Pittsburg, Pa.

BIRD, John D. (1909), Asst. Genl. Mgr., H. R. Worthington, Harrison, and *for mail,* 100 S. Arlington Ave., East Orange, N. J.

BLAKE, Frederick W. (Affiliate, 1909), Genl. Mgr., United Rys. of Yucatan, and *for mail,* P. O. Box 289, Merida, Yucatan, Mex.

CAHILL, Chas. Adams (Affiliate, 1909), 316 Public Service Bldg., Milwaukee, Wis.

CARPENTER, Rolla C. (1909), Prof. of Expl. Engrg., Sibley College, Cornell Univ., and 125 Eddy St., Ithaca, N. Y.

COLBY, Albert Ladd (1909), Cons. Engr., and Iron and Steel Metallurgist, 447 Lehigh St., S. Bethlehem, Pa.

DALLETT, W. P. (1909), Hydr. Engr. and Contr., 49 N. 7th St., Philadelphia, and Media, Pa.

FAIR, William J. (Affiliate, 1909), Engr., Murray Hill Hotel, New York, N. Y.

HERSCHEL, Winslow H. (Affiliate, 1909), Cons. Engr., Providence Engrg. Wks., 110 Governor St., Providence, R. I.

HULL, A. B. (Affiliate, 1909), Salesman, Fairbanks, Morse Co., 30 Church St., New York, N. Y.

HUNT, Charles B. (1909), Supt. of Constr., Buckeye Eng. Co., and 636 McKinley Ave., Salem, O.

HUSSEY, Wm. Edgerly (1909), Mgr. New York Office, Providence Engrg. Wks., 50 Church St., and 67 W. 92d St., New York, N. Y.

LEHN, Henry Coe (Affiliate, 1908), Draftsman, Williamsville, N. Y.

LYMAN, James (1909), Engr., Western Dist., Genl. Elec. Co., 1047 Monadnock Bldg., Chicago, and 1308 Maple Ave., Evanston, Ill.

MITCHELL, Charles J. (1909), Charge of Design, Fairbanks, Morse Mfg. Co., and *for mail,* 836 College Ave., Beloit, Wis.

O'BRIEN, Thomas (Affiliate, 1909), Mgr., Fulton Motor Car Co., 370 Gerard Ave., and *for mail,* 3217 Decatur Ave., New York, N. Y.

ODE, Randolph Theodore (1909), Secy., Providence Engrg. Wks., Providence, and 557 Fruit Hill Ave., North Providence, R. I.

RATHBUN, Edward (1909), 2d V. P., Rathbun-Jones Engrg. Co., Spencer St., Toledo, O.

ROBERTS, Edmund W. (1909), Mech. Engr., V. P. and Genl. Mgr., The Roberts Motor Co., Sandusky, O.

SCHEFFLER, Frederick A. (1909), The Babcock & Wilcox Co., 85 Liberty St., New York, N. Y., and *for mail,* 293 Ridgewood Ave., Glen Ridge, N. J.

SYKES, George (Affiliate, 1908), Engr. and Builder, 1123 Broadway, New York, N. Y.

THOMAS, Richard H. (Affiliate, 1909), 107 Liberty St., New York, N. Y.

WEEKS, Chas. H. (1909), V. P., Buckeye Eng. Co., Lock Box 175, and 301 McKinley Ave., Salem, O.

COMING MEETINGS

April 10 to May 10

AERONAUTIC SOCIETY

April 14, etc., evenings, weekly meetings, Automobile Club of America, W. 54th St., New York. Secy., Wilbur R. Kimball.

AIR BRAKE ASSOCIATION

May 11–14, annual meeting, Richmond, Va. Secy., F. M. Nellis, 53 State St., Boston, Mass.

AMERICAN ASSOCIATION ELECTRIC MOTOR MANUFACTURERS

May 17–20, annual meeting, Hot Springs, Va.

AMERICAN ELECTROCHEMICAL SOCIETY

May 5–8, annual meeting, Niagara Falls, Ont. Secy., Dr. J. W. Richards, Lehigh University, So. Bethlehem, Pa.

AMERICAN FOUNDRYMEN'S ASSOCIATION

May 18–20, Hotel Sinton, Cincinnati, O. Secy., Richard Moldenke, Watchung, N. J.

AMERICAN GAS POWER SOCIETY

April 27, quarterly meeting, Minneapolis, Minn. Secy., R. P. Gillette.

AMERICAN GEOGRAPHICAL SOCIETY

April 20, 29 W. 39th St., New York, 8 p.m. Secy., Geo. H. Hurlbut.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

April 9, monthly meeting, 33 W. 39th St., New York, 8 p.m. Subject: Engineering Education. Secy., R. W. Pope.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

April 16, monthly meeting, Toronto section. Secy. *pro tem.*, W. H. Eisenheis, 1207 Traders' Bank Bldg.

AMERICAN MATHEMATICAL SOCIETY

April 24, Columbia University, New York. Chicago section, April 9, 10, regular meeting, University of Chicago. Secy., H. E. Slaught, 58th St. and Ellis Ave., Chicago.

AMERICAN PORTLAND CEMENT MANUFACTURERS

April 12–14, quarterly meeting, Bellevue-Stratford Hotel, Philadelphia, Pa. Secy., Percy H. Wilson, Land Title Bldg.

AMERICAN RAILWAY ASSOCIATION

May 19, annual meeting, New York. Secy., W. F. Allen, 24 Park Pl.

AMERICAN SOCIETY OF CIVIL ENGINEERS

April 21, May 5, semi-monthly meetings, 220 W. 57th St., New York. Secy., C. W. Hunt.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS

May 1, 29 W. 39th St., New York, 8.30 p.m. Pres., H. Pickler.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

April 13, monthly meeting, 29 W. 39th St., New York; May 4–7, Spring Meeting, Washington, D. C. Secy., C. W. Rice, 29 W. 39th St.

ARCHITECTURAL INSTITUTE OF CANADA

April 6, special General Meeting, Toronto. Secy., Alcide Chaussé, Montreal.

BLUE ROOM ENGINEERING SOCIETY

May 6, 29 W. 39th St., New York, 8 p.m Secy., W. D. Sprague.

BOSTON SOCIETY OF CIVIL ENGINEERS

April 21, monthly meeting, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

BROOKLYN ENGINEERS' CLUB

April 1, 197 Montague St. Paper: The Pennsylvania Railroad Tunnel, J. H O'Brien and Schuyler Hazard. Secy., Joseph Strachan.

CANADIAN FREIGHT ASSOCIATION

April 9, annual meeting. Secy., T. Marshall, Toronto.

CANADIAN RAILWAY CLUB

May 4, monthly meeting, Windsor Hotel, Montreal, 8 p.m. Secy., Jas Powell, St. Lambert, Montreal.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Manitoba Branch

May 6, monthly meeting, University of Manitoba. Secy., E. Brydone Jack

CANADIAN SOCIETY OF CIVIL ENGINEERS, Quebec Branch

April 16, General Section Meeting; April 23, electrical section; April 30, business meeting; May 7, mechanical section, 413 Dorchester St., W., Montreal. Secy., Prof. C. H. McLeod.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Toronto Branch

April 22, regular meeting, 96 King St., W. Secy., T. C. Irving, Jr.

CAR FOREMEN'S ASSOCIATION OF CHICAGO

April 12, May 10, monthly meetings. Secy., Aaron Kline, 326 N. 50th St.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

April 13, Cincinnati, O., 11 a.m. Secy., O. G. Fetter.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

April 14, Columbus, O.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

May 3, Indianapolis, Ind. Secy., G. B. Staats, care Penna. Lines.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

April 12, Kansas City, Mo. Secy., F. H. Ashley, Gumbel Bldg.

CENTRAL ASSOCIATION OF RAILROAD OFFICERS

April 20, Peoria, Ill.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA

April 20, monthly meeting, Rossin House, Toronto, Ont. Secy., C. L. Worth, Room 409, Union Sta.

CENTRAL RAILWAY CLUB

May 14, monthly meeting, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Secy., H. D. Vought, 95 Liberty St., New York.

CLEVELAND ENGINEERING SOCIETY

April 13, monthly meeting, Caxton Bldg. Paper: Power Plant Equipment, F. W. Ballard. Secy., Joe C. Beardsley.

COLORADO SCIENTIFIC SOCIETY

May 1, monthly meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EASTERN RAILROAD ASSOCIATION

May 13, annual meeting. Secy., John J. Harrower, 614 F St., N.W., Washington, D. C.

ENGINEERING ASSOCIATION OF THE SOUTH

April 20, monthly meeting, Nashville section, Carnegie Library Bldg. Section Secy., H. H. Trabue, Berry Blk.

ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA

May 4, monthly meeting, Iowa City. Secy., Dean Wm. G. Raymond.

ENGINEERS' AND ARCHITECTS' CLUB

April 19, monthly meeting, 303 Norton Bldg., Louisville, Ky. Secy., Pierce Butler.

ENGINEERS' CLUB OF BALTIMORE

May 1, monthly meeting. Secy., R. K. Compton, City Hall.

ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA

May 4, monthly meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher.

ENGINEERS' CLUB OF CINCINNATI

April 15, monthly meeting, 25 E. 8th St. Secy., E. A. Gast, P. O. Box 333.

ENGINEERS' CLUB OF PHILADELPHIA

April 17, May 1, semi-monthly meetings, 1317 Spruce St. Secy., H. G. Perring.

ENGINEERS' CLUB OF TORONTO

April 15, etc., weekly meetings, 96 King St., W. Secy., R. B. Woolsey.

ENGINEERS' SOCIETY OF MILWAUKEE

April 14, monthly meeting, 456 Broadway. Secy., W. Fay Martin.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

April 20, regular meeting; May 4, sectional meeting. Secy., E. K. Hiles.

EXPLORERS' CLUB

May 7, 29 W. 39th St., New York, 8.30 p.m. Secy., H. C. Walsh.

GENERAL SUPERINTENDENTS' ASSOCIATION OF CHICAGO

April 14, Chicago. Secy., H. D. Judson, C. B. & Q. R. R.

ILLUMINATING ENGINEERING SOCIETY

April 8, May 13, monthly meetings, New York section, 29 W. 39th St., 8 p.m. Secy., P. S. Millar.

INTERNATIONAL MASTER BOILER-MAKERS' ASSOCIATION

April 27–30, convention, Hotel Sealbach, Louisville, Ky. Secy., H. D. Vought, 95 Liberty St., New York. Standardizing Blue Prints for Building Boilers; Boiler Explosions; Best Method of Applying Flues, Best Method for Caring for Flues While Engine is on the Road and at Terminals, and Best Tools for Same; Flexible Staybolts Compared with Rigid Bolts; Best Method of Applying and Testing Same; Steel vs. Iron Flues, What Advantage and What Success in Welding Them; Best Method of Applying Arch Brick; Standardizing of Shop Tools; Standardizing of Pipe Flanges for Boilers and Templets for Drilling Same; Which is the long way of the Sheet; Best Method of Staying the Front Portion of Crown Sheet on Radial Top Boiler to Prevent Cracking of Flue Sheet in Top Flange; Rules and Formulas; Senate Bill.

IOWA ELECTRICAL ASSOCIATION

April 21, 22, annual meeting, Cedar Rapids. Secy., W. N. Keiser, Des Moines.

IOWA RAILWAY CLUB

April 9, May 14, monthly meetings, Des Moines. Secy., W. B. Harrison, Union Sta.

LOUISIANA ENGINEERING SOCIETY

April 12, May 10, monthly meetings, 323 Hibernia Bldg., New Orleans. Secy., L. C. Datz.

MASSACHUSETTS STREET RAILWAY ASSOCIATION

April 14, monthly meeting, Boston. Secy., Chas. S. Clark, 70 Kilby St.

MISSOURI ELECTRIC LIGHT, GAS AND RAILWAY ASSOCIATION

April 15–17, annual convention, Springfield. Secy., C. L. Clary, Sikeston.

MODERN SCIENCE CLUB

April 6, regular meeting, 125 S. Elliott Pl., Brooklyn, N. Y. Paper: Electric Motor Design, C. A. Lundell. April 13, annual election. Secy., Jas. A. Donnelly.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK

April 28, 29 W. 39th St., 8.15 p.m. Secy., C. D. Pollock.

MUSURGIA SOCIETY

April 15, 29 W. 39th St., New York, 8 p.m. Secy., F. M. Frobisher.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS

May 5, monthly meeting, New York. Secy., C. C. Hildebrand, 7 E. 42d St.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS

April 28, 29, annual meeting, Mechanics Bldg., Boston, Mass. Secy., C. J. H. Woodbury, P. O. Box 3672.

NATIONAL ASSOCIATION OF MANUFACTURERS

May 11, annual meeting, New York. Secy., Geo. S. Boudinot, 170 Broadway.

NATIONAL FIRE PROTECTION ASSOCIATION

May 25–27, annual meeting, New York. Secy., W. H. Merrill, 382 Ohio St., Chicago, Ill.

NATIONAL RAILWAY WATER SUPPLY ASSOCIATION

April 11, Minneapolis, Minn. Secy., F. W. Hayden, Glencoe.

NATURAL GAS ASSOCIATION OF AMERICA

May 18–20, Columbus, O. Secy., J. F. Owens, Wagoner, Okla.

NEW ENGLAND RAILROAD CLUB

April 13, monthly meeting, Copley Square Hotel, Boston, Mass., 8 p. m. Paper: Smoke Prevention in Relation to Combustion, George F. Baker. Secy., Geo. H. Frazier, 10 Oliver St.

NEW ENGLAND STREET RAILWAY CLUB

April 22, monthly meeting, American House, Boston, Mass. Secy., John J. Lane, 12 Pearl St.

NEW YORK RAILROAD CLUB

April 16, monthly meeting, 29 W. 39th St., 8.15 p.m. Secy., H. D. Vought, 95 Liberty St.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS

April 13, etc., weekly meetings, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NEW YORK TELEPHONE SOCIETY

April 20, monthly meeting, 29 W. 39th St., 8 p.m. Secy., T. H. Laurence.

NORTHERN RAILWAY CLUB

April 24, monthly meeting, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWEST RAILWAY CLUB

April 13, May 11, monthly meetings, Minneapolis, Minn. Secy., T. W. Flannagan, care Soo Line.

NOVA SCOTIA SOCIETY OF ENGINEERS
April 8, May 13, monthly meetings, Halifax. Secy., S. Fenn.
OPTOMETRICAL SOCIETY OF THE CITY OF NEW YORK
April 14, 29 W. 39th St., 8 p.m. Secy., J. H. Drakeford.
PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
April 27, monthly meeting, Technical High School Hall, 8 p.m. June 22, annual meeting. Secy., T. M. Phetteplace.
PURDUE MECHANICAL ENGINEERING SOCIETY
April 14, etc., fortnightly meetings, Purdue University, Lafayette, Ind., 6.30 p.m. Secy., L. B. Miller.
RAILWAY CLUB OF KANSAS CITY
April 16, Kansas City, Mo.
RAILWAY CLUB OF PITTSBURGH
April 23, monthly meeting, Monongahela House, 8 p.m. Secy., J. D. Conway, Genl. Office, P. & L. E. R. R.
RAILWAY SIGNAL ASSOCIATION
May 11, Chicago, Ill. Secy., C. C. Rosenberg, 712 North Linden St., Bethlehem, Pa.
RENSSELAER SOCIETY OF ENGINEERS
April 23, etc., fortnightly meetings, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.
RICHMOND RAILROAD CLUB
April 12, Richmond, Va. Secy., F. O. Robinson, care C. & O. R. R.
ROCHESTER ENGINEERING SOCIETY
April 9, May 14, monthly meetings. Secy., John F. Skinner, 54 City Hall.
ST. LOUIS RAILWAY CLUB
April 9, monthly meeting, Southern Hotel, 8 p.m. Secy., B. W. Frauenthal.
SCRANTON ENGINEERS' CLUB
April 15, monthly meeting, Board of Trade Bldg. Secy., A. B. Dunning.
SHORT LINE RAILROAD ASSOCIATION
May 3, New York. Secy., Cromwell G. Macy, Jr., Nantucket Central R. R., 257 Broadway.
SOUTHERN AND SOUTHWESTERN RAILWAY CLUB
April 15, monthly meeting, Atlanta, Ga. Secy., A. J. Merrill, 218 Prudential Bldg., Atlanta.
SOUTHERN ASSOCIATION OF CAR SERVICE OFFICERS
April 15, Atlanta, Ga.
SOUTHWESTERN ELECTRICAL AND GAS ASSOCIATION
May, annual convention, Dallas, Texas.
TECHNICAL SOCIETY OF BROOKLYN
April 16, semi-monthly meeting, Arion Hall, Arion Pl., 8.30 p.m. Pres., M. C. Budell, 20 Nassau St., New York.
TECHNOLOGY CLUB OF SYRACUSE
April 14, May 12, monthly meetings, 502 Bastable Blk., 8 p.m. Secy., Robert L. Allen.
WESTERN RAILWAY CLUB
April 20, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Joseph W. Taylor, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS

April 21. Paper: Protective Coatings for Structural Materials, R. S. Perry. April 14, Electrical section, Chicago, Ill. Secy., T. H. Warder, 1737 Monadnock Blk., Chicago.

WISCONSIN GAS ASSOCIATION

May 12, 13, annual convention, Milwaukee. Secy., Henry H. Hyde, Racine.

MEETINGS TO BE HELD IN ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
April			
13	N. Y. Society Accountants and Bkprs	T. L. Woolhouse	8:00
13	American Society Mechanical Engineers	C. W. Rice	8:00
14	Optometrical Society of City of N. Y	J. H. Drakeford	8:00
15	Musurgia Society	F. M. Frobisher	8:00
16	New York Railroad Club	H. D. Vought	8:15
20	American Geographical Society	Geo. H. Hurlbut	8:00
20	N. Y. Society Accountants and Bkprs	T. L. Woolhouse	8:00
20	New York Telephone Society	T. H. Laurence	8:00
27	N. Y. Society of Accountants and Bkprs	T. L. Woolhouse	8:00
28	Municipal Engineers of New York	C. D. Pollock	8.15
May			
1	Amer. Soc. Hungarian Engrs & Archts	H. Pickler (Pres.)	8:30
4	N. Y. Society Accountants and Bkprs	T. L. Woolhouse	8:00
6	Blue Room Engineering Society	W. D. Sprague	8:00
7	Explorers Club	H. C. Walsh	8:30

NEW BOOKS

Water Power Engineering. The Theory, Investigation and Development of Water Powers. By Daniel W. Mead, Consulting Engineer; Professor of Hydraulic and Sanitary Engineering, University of Wisconsin. *McGraw Publishing Co., New York,* 1908. 8vo, cloth, viii+787 pp. Price, $6.00 net.

In the development of a water power project, the engineer is frequently called upon to do more than design and construct the power plant. He has to consider the adequacy of the supply, the power available, the cost, and many other preliminary problems, and the author has therefore discussed at length the fundamental principles which must form the basis of a successful water power development. Much the smaller part of the book is devoted to the theory of hydraulics and of design and much the larger part to the broader considerations of water power development, turbine analysis and selection, and other controlling features upon which but little positive information has usually been available. In this connection those who attended the Detroit meeting of the Society will remember the excellent discussion upon surge tanks by Mr. L. F. Harsa, which he then stated was based upon material prepared by him under the direction of Professor Mead for use in this book which was then in process. This matter is included in the chapter on Governing, and it may be taken as a fair indication of the thoroughness with which the author has worked up the various chapters. At the end of each chapter is a list of literature upon the subjects covered, affording the student and engineer an opportunity to investigate further any subject in which he is interested.

Contents, by chapter headings: Introduction; Power; Hydraulics; Water Power; Rainfall; The Disposal of the Rainfall; Run-off; Stream Flow; The Measurement of Stream Flow; Water Wheels; Turbine Details and Appurtenances; Hydraulics of the Turbine; Turbine Testing; The Selection of the Turbine; The Load Curve and Load Factors, and Their Influence on the Design of the Power Plant; The Speed Regulation of Turbine Water Wheels; The Water Wheel Governor; Arrangement of the Reaction Wheel; The Selection of Machinery and Design of Plant; Examples of Water Power Plants; The Relation of Dam and Power Station; Principles of Construction of Dams; Appendages to Dams; Pondage and Storage; Cost, Value and Sale of Power; The Investigation of Water Power Projects; Appendices.

The Temperature-Entropy Diagram. By Charles W. Berry, Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology. *John Wiley & Sons, New York.* 1908. Second edition revised and enlarged. Cloth, 12mo, xviii+299 pp. 109 figures. Price, $2.00 net.

In order to use this little book, the reader must have previously been a student of thermo-dynamics, but to such as have a good acquaintance with the subject it will prove a useful handbook on practically the whole range of subjects covered by the science. The treatment is both by temperature-entropy diagram and by formula, the explanation of the diagrams and formulas following along together, thus making plain to the reader the heat changes that actually occur as well as

giving him the means for calculating the changes numerically. To show the method of treatment and the degree of completeness, reference may be made to a single chapter—that of The Flow of Fluids. This takes up by diagram and by formula, on the principle of the transfer of energy, the flow of gases, of saturated and superheated steam, design of nozzles, loss of availability through throttling, the throttling calorimeter, the principles by which the specific heat of superheated steam is determined, adiabatic expansion with and without friction loss, etc. In the present edition, a chapter is given explaining Mollier's total energy-entropy diagram.

Contents, by chapter headings: General Discussion; The Temperature-entropy Diagram for Perfect Gases; The Temperature-entropy Diagram for Saturated Steam; The Temperature-entropy Diagram for Superheated Vapors; The Temperature-entropy Diagram for the Flow of Fluids; Mollier's Total Energy-entropy Diagram; Thermodynamics of Mixtures of Gases and Vapors, and of Vapors; The Temperature-entropy Diagram Applied to Hot-Air Engines; The Temperature-entropy Diagram Applied to Gas-engine Cycles; The Gas-engine Indicator Card; The Temperature-entropy Diagram Applied to the Non-conducting Steam-engine; The Multiple-fluid or Waste heat Engine; The Temperature-entropy Diagram of the Actual Steam-engine Cycle; Steam-engine Cylinder Efficiency; Liquefaction of Vapors and Gases; Application of the Temperature-entropy Diagram to Air-compressors and Air-motors; Discussion of Refrigerating Processes and the Warming Engine; Table of Properties of Saturated Steam from 400° F., to the Critical Temperature.

THE MECHANICAL ENGINEERING OF STEAM POWER PLANTS. By Frederick Remsen Hutton, E.M., Sc.D. *John Wiley & Sons, New York.* 1908. Third edition, rewritten, Cloth, 8vo, xli+825 pp., 697 illustrations. Price $5.

The first edition of this work was issued in 1897 and filled a new place in literature upon the power plant. The treatise was prepared for the business engineer, the contractor, and the man who buys or installs machinery and is interested in power-plant economy as affected by the relations of one unit to another, rather than by the minute details of design. It contained a comprehensive description of all the apparatus of the power plant and it had as a characteristic feature a statement of the advantages or disadvantages of the different types of apparatus and of different methods of operation, with a view to placing before the reader the fundamental considerations in power plant equipment. In the new edition the same plan is followed, but amplified to cover more important power house problems and more attention is given to the principles of mechanics related to the subject. This edition has been entirely rewritten, with much new matter, and its object, as outlined above, is further indicated by the statement in the preface to the effect that while there are few engineers called upon to design and construct any detail of the power plant, all are sure to be called upon to buy some or all of these elements or to design power plants as a whole in which such elements are to function. Hence the importance of training in the process of selection and of critically weighing arguments for and against apparatus.

Contents, by chapter headings: *Part I.* Introductory; The Function of the Power Plant; Sources of Motor Energy for the Power Plant; Internal and External Combustion; Measurements of the Work Unit of Output; Indicated Horsepower; Brake Horsepower; Elements and Analysis of the Steam Power Plant; The Quantitative Basis of the Steam Power Plant. *Part II.* The Boiler: Forms, Material and Manufacture; Boiler; Riveting, Staving and Structural Details: Fire-Tube Boilers Externally Fired; Fire-Tube Boilers Internally Fired; Water Tube Boilers; Coil and Pipe Boilers; Flash and Semi-Flash Boilers; Boiler Furnaces, Chimneys and Settings;

Firing Boilers with Gas or Liquid Hydro-carbon or with Pulverized Fuel; Boiler Accessory Apparatus; Care and Management of Boilers; Boiler Inspection and Testing; Boiler Explosions. *Part III.* Boiler Plant Auxiliaries. *Part IV.* The Piping of Pressure to the Engine and its Accessories. *Part V.* The Engine; Expansive Working of Steam; The Compound and Multiple Expansion Engine; The Rotary Steam Engine; The Steam Turbine; Engine Foundation and Bed-Plate; Engine Cylinder, Piston and Piston-Rod; Cross-Head, Guides and Connecting-Rod; Crank-Shaft, Eccentric, Fly-Wheel; Valves and Valve Gearing; Valve Gearing Design; Special Forms; Valve Gearing; Balanced Valves; Cam and Trip Valve-Gear; Reversing Valve Gears; Link Motions; Valve Gears for Variable Cut-off; Governing and Governors for Steam Engines. *Part VI.* Engine Auxiliaries: The Condenser and Attachments; Engine Auxiliaries, Lubricators and Lubrication. *Part VII.* Care and Management; Accidents; Testing the Power Plant for Economy and Efficiency. *Part VIII.* General Remarks upon the Power Plant. *Part IX.* Appendices; Historical Summary; Steam Tables; Table Hyperbolic Logarithms; Historic Illustrations.

OFFICERS AND COUNCIL

PRESIDENT

Jesse M. Smith .... New York

VICE-PRESIDENTS

L. P. Breckenridge .... Urbana, Ill.
Fred J. Miller .... Center Bridge, Pa.
Arthur West .... E. Pittsburg, Pa.

Terms expire at Annual Meeting of 1909

Geo. M. Bond .... Hartford, Conn.
R. C. Carpenter .... Ithaca, N. Y.
F. M. Whyte .... New York

Terms expire at Annual Meeting of 1910

PAST PRESIDENTS

Members of the Council for 1909

Ambrose Swasey .... Cleveland, O.
John R. Freeman .... Providence, R. I.
Frederick W. Taylor .... Philadelphia, Pa
F. R. Hutton .... New York
M. L. Holman .... St. Louis, Mo.

MANAGERS

G. M. Basford .... New York
A. J. Caldwell .... Newburg, N. Y.
A. L. Riker .... Bridgeport, Conn.

Terms expire at Annual Meeting of 1909

Wm. L. Abbott .... Chicago, Ill.
Alex. C. Humphreys .... New York
Henry G. Stott .... New Rochelle, N. Y.

Terms expire at Annual Meeting of 1910

H. L. Gantt .... Pawtucket, R. I.
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt .... New York

HONORARY SECRETARY

F. R. Hutton .... New York

SECRETARY

Calvin W. Rice .... 29 W. 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
Alex. C. Humphreys
F. R. Hutton
Fred J. Miller
Frederic M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Edward F. Schnuck (2)
J. Waldo Smith (3)
Robert M. Dixon (4)
Waldo H. Marshall (5)

MEETINGS

Willis E. Hall (1), *Chairman*
Wm. H. Bryan (2)
L. R. Pomeroy (3)
Charles E. Lucke (4)
H. de B. Parsons (5)

PUBLICATION

Arthur L. Williston (1), *Chairman*
D. S. Jacobus (2)
H. F. J. Porter (3)
H. W. Spangler (4)
Geo, I. Rockwood (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Charles R. Richards (2)
Francis H. Stillman (3)
George J. Foran (4)
Hosea Webster (5)

LIBRARY

H. H. Suplee (1)
Ambrose Swasey (2)
Leonard Waldo (3)
John W. Lieb, Jr. (4), *Chairman*
Chas. L. Clarke (5)

HOUSE COMMITTEE

Henry S. Loud (1), *Chairman*
William Carter Dickerman (2)
Bernard Victor Swenson (3)
Francis Blossom (4)
Edward Van Winkle (5)

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philp De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Charles Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
Charles Whiting Baker
L. D. Burlingame
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
R. C. Carpenter
Charles Wallace Hunt
J. W. Lieb, Jr.
Fred J. Miller

On Revision and Extension of the Code for Testing Gas Power Machinery

Charles E. Lucke, *Chairman*
E. T. Adams
Geo. H. Barrus
D. S. Jacobus
Arthur West

On Hudson-Fulton Celebration

Geo. W. Melville
M. L. Holman
Jesse M. Smith

SOCIETY REPRESENTATIVES
1909

On John Fritz Medal

Henry R. Towne (1) — F. R. Hutton (3)
Ambrose Swasey (2) — Charles Wallace Hunt (4)

On Board of Trustees United Engineering Societies Building

Chas. Wallace Hunt (1) — F. R. Hutton (2)
Fred J. Miller (3)

On Joint Library Committee

The Chairman of the Library Committee of The Am. Soc. M E.

On National Fire Protection Association

ohn R. Freeman — Ira H. Woolson

On Joint Committee on Engineering Education

Alex. C. Humphreys — F. W. Taylor

On Government Advisory Board on Fuels and Structural Materials

Geo. H. Barrus — P. W. Gates
W. F. M. Goss

On Advisory Board National Conservation Commission

Geo. F. Swain — John R. Freeman
Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys — Fred J. Miller

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION
1909

CHAIRMAN
F. R. Low

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman, *Chairman*
G. I. Rockwood
F. R. Hutton
H. H. Suplee
R. H. Fernald

GAS POWER MEMBERSHIP COMMITTEE

Robert T. Lozier, *Chairman*
D. B. Rushmore
Albert A. Cary
A. F. Stillman
H. V. O. Coes
G. M. S. Tait
A. E. Johnson
George W. Whyte
F. S. King
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
E. S. McClelland
R. T. Kent
C. W. Obert
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
L. N. Ludy
H. R. Cobleigh
L. S. Marks
G. D. Conlee
T. M. Phetteplace
R. S. deMitkiewicz
G. J. Rathbun
H. T. Eddy
W. Rautenstrauch
L. V. Goebbels
S. A. Reeve
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

J. R. Bibbins, *Chairman*
A. Bement
L. B. Lent

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
G. L. Knight
W. H. Blauvelt
J. L. Lyon
E. P. Coleman
D. T. McLeod
C. J. Davidson
V. E. McMullen
H. J. K. Freyn
J. P. Sparrow
N. T. Harrington
Paul Winsor
C. H. Parker
C. W. Whiting
J. B. Klumpp
W. T. Donnelly
V. Z. Caracristi
T. H. Yawger
F. W. Walker
A. B. Steen

STANDARDIZATION COMMITTEE

Dr. Charles E. Lucke, *Chairman*
E. T. Adams
Arthur West
J. D. Andrews
J. R. Bibbins
H. F. Smith
Lewis Doeling

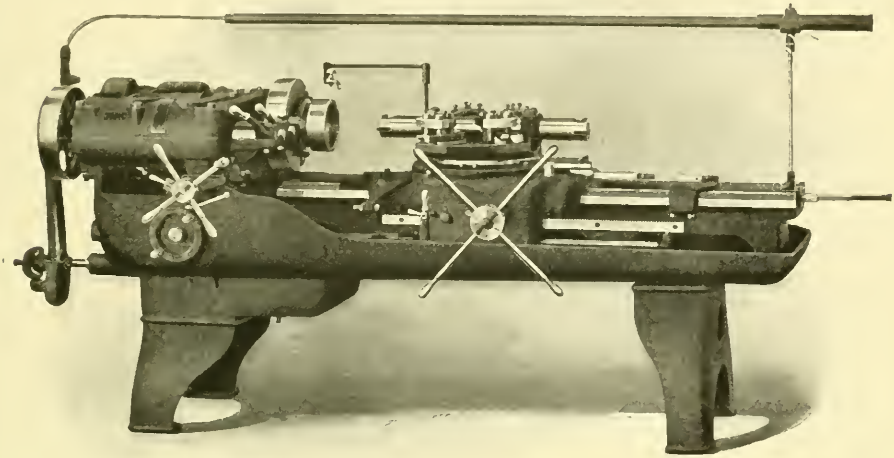
ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment

The Hartness Flat Turret Lathe

mailed on request



The ten stops for the cross-feed head, combined with the dozen stops for the turret, and the turning and boring tools, all of the simplest and stiffest construction, make this machine ready to begin work as soon as it is supplied with the driving power. It is not only ready to begin work on the work for which it may have been purchased, but it is supplied with a set of tools that will take care of any similar piece any hour or any day in the future; and, notwithstanding this universality, adaptability and efficiency, our tools and work are brought together under the most rigid control and under ideal conditions never before attained in a lathe.

All the shears and running surfaces are protected from the dust of cast-iron, so that the machine may be used for either steel work in which oil is used, or for cast-iron chucking.

Machine Company Queen Victoria St. London, England

France and Spain, Ph. Bonvillain and E. Ronceray, 9 and 11 Rue des Envierges, Paris. Italy, Adler & Eisenschitz, Milan.

YEAR BOOKS

The Society wishes to have a file of year books or catalogues complete since its formation. Will members who have any of the following numbers either send them to the Society or correspond with the Secretary

No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

The American Society of Mechanical Engineers
29 West 39th Street, New York

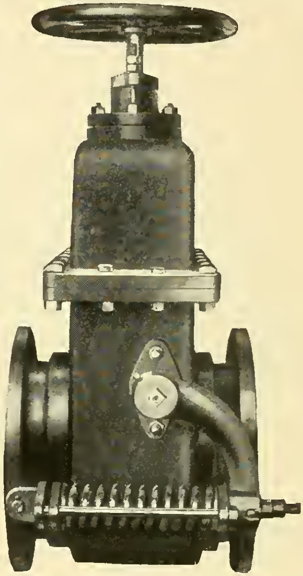
ADVERTISING SUPPLEMENT

SECTION 2

Power Plant Equipment

NELSON VALVE COMPANY
Number 576
NELSON VALVE COMPANY
Electrically Controlled Gate Valves Number 576
THESE valves are used with advantage when it is necessary to place the valves in inaccessible or dangerous positions or when, either for convenience or emergency, they are controlled from a long distance; or when it is desirable to control all the valves in a system from one point, or when frequent or rapid closing is required
The switch that controls this valve is provided with high and low limit. To close the valve it is only necessary to throw the switch into contact, the gates then close rapidly until they are tightly seated, when the switch is automatically thrown out, immediately stopping the movement The valve is opened in the same simple manner Our method of control provides for manually setting the valve partially open at any position if desired.
These valves are furnished in any size and for any pressure Prices will be quoted on application.

The Erwood Swing Gate Valve



Stands alone in a class by itself as a **Back Pressure Valve.** **WHY**—A good back pressure valve should be ABLE TO OPERATE IN ANY POSITION. It should permit of being thrown in and out WITHOUT CHANGING THE ADJUSTMENT. It should offer NO OBSTRUCTION TO THE EXHAUST STEAM during the summer months. It should be STRAIGHTWAY. It should be constructed so that the disc can be removed from the passage of the steam without taking it apart. IT SHOULD NOT BE CONTROLLED BY WEIGHTS. IF A WEIGHTED LEVER IS OUT OF DATE FOR A SAFETY VALVE ON YOUR BOILER, IT IS ALSO OBSOLETE AS A RELIEF FOR YOUR BACK PRESSURE, OPEN HEATERS, TANKS, ETC.

Does any valve except the ERWOOD FILL AND COMPLY WITH ALL THESE REQUIREMENTS?

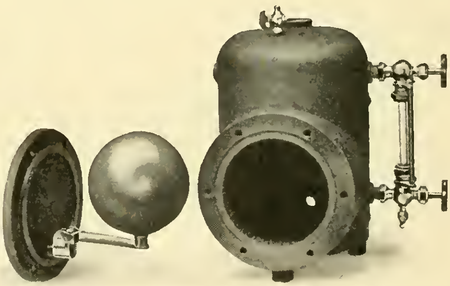
Not being a Gravity Valve, it is NOISELESS in operation.

THE ERWOOD is made in but one style only. It makes NO DIFFERENCE HOW YOU PLACE IT, or where. There are no dash pots or cushions; no water cavities to freeze up.

Write for Catalogue D

WALCH & WYETH, 87 Lake St., Chicago

LINDSTROM'S CORLISS VALVE STEAM TRAP



JOHN T. LINDSTROM

214 South Third Street

ALLENTOWN, PA.

The Anderson

TRIPLE ACTING

Non-Return VALVES

"Work Both Ways"

Protect Your Power Station with the Valves that are Absolutely Guaranteed

Armour & Co. Chicago, ordered 32 10″ Triple Valves

GOLDEN-ANDERSON Valve Specialty Co.

1032 Fulton Building
Pittsburg, Pa.

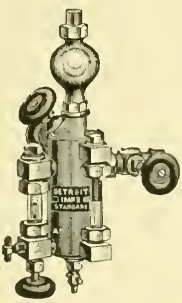
The Controlling Altitude Valve

maintains a uniform stage of water in standpipes, reservoirs or tanks.

NO FLOAT FIXTURES

No overflow in case of fire. Pressure. Valves closed by water and electricity

Valves and Traps
For Steam and Water Service



"DETROIT"
Improved Standard LUBRICATORS

Insure perfect operation

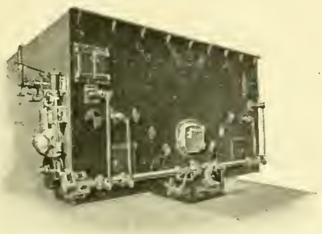
THE GENUINE "DETROIT"

Is simple and dependable. (Look out for substitutes).

Leading engineers the world over specify the "Detroit" to the exclusion of all other makes. Write for Book "A15." It contains information of value to all mechanical engineers

DETROIT LUBRICATOR COMPANY

DETROIT, U. S. A.



The reciprocating feed

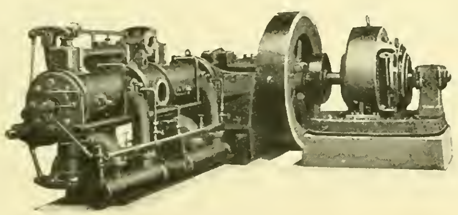
DETROIT STOKER

is recommended for large installations when coal is to be handled by machinery

IT BURNS ALL KINDS OF FUEL ECONOMICALLY

Send for our New Catalogue

Detroit Stoker and Foundry Co., Detroit, Mich.



Valve troubles are obviated in Du Bois Gas and Gasoline Engines (5 to 375 H. P.). The valves are solid steel forgings, carried in independent cages in valve chest, and can be quickly taken out, examined and replaced. The valve seat is also withdrawn at the same time.

Catalog "P," free on request, describes other points of excellencies.

DU BOIS IRON WORKS, 816 Brady St., Du Bois, Pa.

HEAT DOES NOT AFFECT

DIXON'S FLAKE GRAPHITE

Do you realize what this means? Heat affects oil and grease—great heat disintegrates both. But heat DOES NOT affect Dixon's Flake Graphite.

The advantage of its use in steam and gas engine cylinders, and cylinders of air compressors is therefore obvious,

There are a lot of other good points about Dixon's Flake Graphite. Write us for further information—it may easily prove valuable to you.

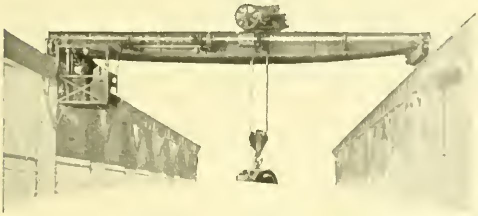
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

ADVERTISING SUPPLEMENT

SECTION 3

Hoisting and Conveying Machinery
Power Transmission
Engineering Miscellany

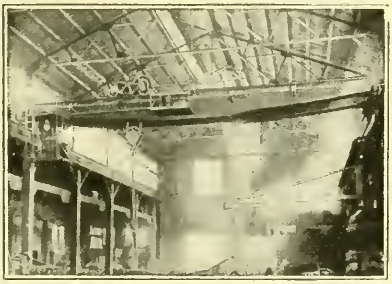
CLEVELAND CRANES



are so built that they will give the finest mechanical service possible from any hoists made.

THE CLEVELAND CRANE & ~~CAR CO.~~ ENGINEERING CO.
— WICKLIFFE, OHIO. —

Our catalogue is an invaluable reference book. Do you want one?



ELECTRIC TRAVELERS
All Types for Every Service

COMPLETE EQUIPMENT

AND CRANES OF ALL KINDS FOR

GREY IRON, STEEL AND MALLEABLE

FOUNDRY PLANTS

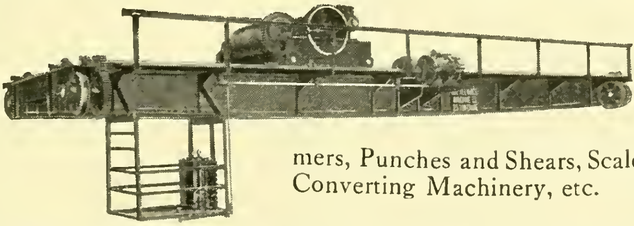
Buildings designed and furnished. Equipment installed and operated. Plant delivered to purchasers ready to run.

WHITING FOUNDRY EQUIPMENT CO.

Manufacturers, Engineers, Designers

HARVEY, ILL. (Chicago, suburb)

ALLIANCE CRANES All Types



Also Rolling Mill and Hydraulic Machinery, Steam Hammers, Punches and Shears, Scale Cars, Copper Converting Machinery, etc.

THE ALLIANCE MACHINE CO. ALLIANCE, OHIO

Pittsburg Office, Frick Building. Birmingham Office, Woodward Building

---

ELEVATING, CONVEYING, POWER TRANSMITTING MACHINERY

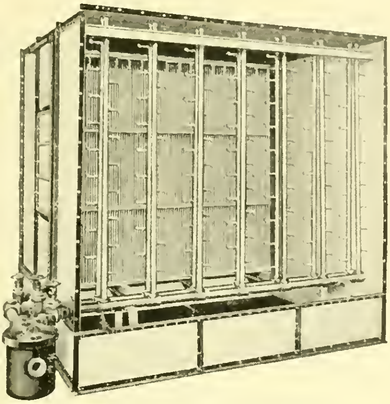
Designers and Builders of Coal and Ash Handling systems, Cars, Industrial Track, etc., Silent Chain and all Standard Chains. Manufacturers of Clouser Detachable Link Chain Belt.

Write for Catalogue No. 20

LINK CHAIN BELT CO.

52 Dey Street - - - - - - NEW YORK

THE CARRIER AIR WASHER AND HUMIDIFIER



Carrier Air Washer and Humidifier

Thoroughly washes all air passing through it, removing all solid particles of dust and soot.

Removes all free moisture held in suspension as a result of washing process.

Maintains automatically any desired humidity in the building accurately by thermostatic control.

Supplies automatically and instantaneously the exact quantity of steam required for evaporation of moisture governed by the requirements of the thermostat.

Does over one-half the tempering of the air, thus eliminating the usual heating coil in front of the washer with great gain in efficiency.

Cools air passing through it in summer without the use of cold water.

CARRIER AIR CONDITIONING CO.

OF AMERICA

39 Cortlandt St., New York

123-C

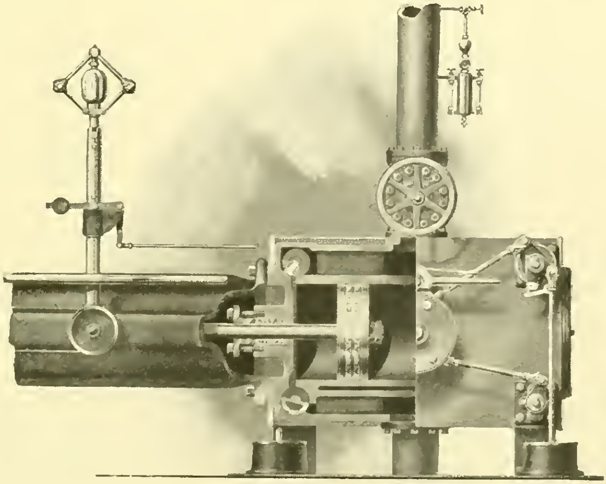
Facing pistons with Allan Metal prevents scoring of cylinder, reduces friction, wear and maintenance cost.

A. ALLAN & SON, 490 Greenwich St., N. Y.

Write for our Booklet

The Heart of the Engine

The Seat of Power



ENGINEERING SCHOOLS AND COLLEGES

PROFESSIONAL CARDS

CLASSIFIED LIST OF ADVERTISERS

AIR CONDITIONING.

Carrier Air Conditioning Co., New York.

AIR WASHING.

Carrier Air Conditioning Co., New York.

ARBORS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

AUTOMATIC MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.

AUTOMATIC STOKERS.

Detroit Stoker & Foundry Co., Detroit, Mich.

BARRELS, TUMBLING.

Whiting Foundry Equipment Co., Harvey, Ill.

BELTING, CHAIN.

Link Belt Co., Philadelphia, Pa.
Link Chain Belt Co., New York.

BELTING, LEATHER.

Schieren Co., Chas. A., New York.

BLOWERS, POSITIVE PRESSURE.

American Gas Furnace Co., New York.

BLOW PIPES AND BLOWERS.

American Gas Furnace Co., New York.

BLUE PRINTING MACHINES.

Buckeye Engine Co., Salem, O.

BOILERS.

Heine Safety Boiler Co., St. Louis, Mo.
Murray Iron Works Co., Burlington, Iowa.
Robb-Mumford Boiler Co., S. Framingham, Mass.

BORING MILLS.

Manning, Maxwell & Moore, New York.

BOLTS AND NUTS.

Russell, Burdsall and Ward Bolt and Nut Co., Port Chester, N. Y.

BOLT AND NUT MACHINERY.

Manning, Maxwell & Moore, New York.
National Machinery Co., Tiffin, O.

CAR DUMPERS.

Dodge Co., J. M., Philadelphia, Pa.

CAR HAULS, WIRE CABLE.

Jeffrey Mfg. Co., Columbus, O.

CARS, SCALE.

Alliance Machine Co., Alliance, O.

CASE HARDENING MACHINES.

American Gas Furnace Co., New York.

CASTINGS, SPECIAL HEAVY.

Hooven, Owens & Rentschler Co., Hamilton, O.

CENTERING MACHINES.

Whiton Machine Co., D. E., New London, Conn.

CHAINS, DODGE, EWART, LEY, MONOBAR, RENOLD, Etc.

Link Belt Co., Philadelphia, Pa.

CHAIN DRIVES.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHAINS, SPROCKET.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

CHUCKS, DRILL.

Morse Twist Drill & Machine Co., New Bedford, Mass.
Whiton Machine Co., D. E., New London, Conn.

CHUCKS, LATHE.

Whiton Machine Co., D. E., New London, Conn.

CLUTCHES, FRICTION.

Dodge Mfg. Co., Mishawaka, Ind.

COAL AND ASHES HANDLING MACHINERY.

Link Belt Co., Philadelphia, Pa.
Link Chain Belt Co., New York.

COAL CUTTERS.

Jeffrey Mfg. Co., Columbus, O.

COAL STORAGE.

Dodge Co., J. M., Philadelphia, Pa.

COMPRESSORS, AIR.

Riverside Engine Co., Oil City, Pa.

COMPRESSORS, GAS.

Riverside Engine Co., Oil City, Pa.

CONDENSERS, SURFACE, JET AND BAROMETRIC.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

CONVEYING MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Link Chain Belt Co., New York.

COOLING.

Carrier Air Conditioning Co., New York.

COPPER CONVERTING MACHINERY.

Alliance Machine Co., Alliance, O.

COUNTERBORES.

Morse Twist Drill & Machine Co., New Bed ford, Mass.

COUNTERSHAFTS.

Builders Iron Foundry, Providence, R. I.
Dodge Mfg. Co., Mishawaka, Ind.

COUPLING, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

CRANES.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Dodge Co., J. M., Philadelphia, Pa.
Link Belt Co., Philadelphia, Pa.
Manning, Maxwell & Moore, New York.
Whiting Foundry Equipment Co., Harvey, Ill.

CUPOLAS, FOUNDRY.

Whiting Foundry Equipment Co., Harvey, Ill.

CUTTERS, MILLING.

Morse Twist Drill & Machine Co., New Bedford, Mass.

DEHUMIDIFYING.

Carrier Air Conditioning Co., New York.

DIES, AUTO—OPENING

Errington, F. A., New York.

DRILLS.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Standard Tool Co., Cleveland, O.

DRILLS, PORTABLE.

General Electric Co., Schenectady, N. Y.

DRAFTSMAN'S SQUARE.

Kelsey, D. J., New Haven, Conn.

DYNAMOS.

General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway. Pa.

ELECTRICAL MACHINERY.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway. Pa.

ELEVATORS.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

ELEVATING AND CONVEYING MACHINERY.

Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia. Pa.
Link Chain Belt Co., New York.

ENGINEERS.

Arnold Co., The, Chicago, Ill.
Bacon, Earle C., New York City.
Baldwin, Bert L., Cincinnati, O.
Dodge, J. M. Co., Philadelphia, Pa.
Hurley, D. & Co., Providence, R. I.
Link Belt Co., Philadelphia, Pa.
Main, Charles T., Boston, Mass.
O'Neil, J. G., Chicago, Ill.

ENGINEERING COLLEGES.

Clarkson School of Technology, Potsdam, N.Y.
New York University, New York City.
Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Rensselaer Polytechnic Institute, Troy, N. Y.
Tufts College, Tufts College, Mass.
University of Michigan, Ann Arbor, Mich.

ENGINES, GAS.

Buckeye Engine Co., Salem, O.
DuBois Iron Works, DuBois, Pa.
National Meter Co., New York.
Riverside Engine Co., Oil City, Pa.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

ENGINES, STEAM.

American Engine Co., Bound Brook, N. J.
Buckeye Engine Co., Salem, O.
Hooven, Owens & Rentschler Co., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Ridgway Dynamo & Engine Co., Ridgway, Pa.
St. Louis Iron & Machine Works, St. Louis, Mo.
Struthers-Wells Co., Warren, Pa.
Wisconsin Engine Co., Corliss, Wis.

FILES.

American Swiss File and Tool Co., New York.
Reichhelm & Co., E. P., New York.

FORGES, GAS.

American Gas Furnace Co., New York.

FOUNDRY EQUIPMENT.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, ANNEALING AND TEMPERING.

American Gas Furnace Co., New York.

FURNACES.

Whiting Foundry Equipment Co., Harvey, Ill.

FURNACES, GAS.

American Gas Furnace Co., New York.

GAS GENERATORS.

American Gas Furnace Co., New York.

GASKETS.

American Goetze-Gasket & Packing Co., New York.

GASKETS, COPPER.

American Goetze-Gasket & Packing Co., New York.

GAS PRODUCERS.

Struthers-Wells Co., Warren, Pa.

GAGES, WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Manning, Maxwell & Moore, New York.

GEAR CUTTING MACHINES.

Manning, Maxwell & Moore, New York.
Newark Gear Cutting Machine Co., Newark, N. J.
Whiton Machine Co., D. E., New London, Conn.

GEARS.

Dodge Mfg. Co., Mishawaka, Ind.
Newark Gear Cutting Machine Co., Newark, N. J.

GENERATING SETS.

American Engine Co., Bound Brook, N. J.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

GOVERNORS, PUMP.

Albany Steam Trap Co., Albany, N. Y.

GRAPHITE.

Dixon Crucible Co., Jos., Jersey City, N. J.

GRINDERS, TOOL.

Manning, Maxwell & Moore, New York.
Morse Twist Drill & Machine Co., New Bedford, Mass.
Pratt and Whitney Co., Hartford, Conn.

GRINDING AND POLISHING MACHINERY.

Builders Iron Foundry, Providence, R. I.

HAMMERS, STEAM.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

HANGERS, SHAFT.

Dodge Mfg. Co., Mishawaka, Ind.

HEATERS, FEEDWATER.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

HEATING MACHINES.

American Gas Furnace Co., New York.

HOISTING AND CONVEYING MACHINERY.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Jeffrey Mfg. Co., Columbus, O.
Link Belt Co., Philadelphia, Pa.
Whiting Foundry Equipment Co., Harvey, Ill.

HOISTS.

Alliance Machine Co., Alliance, O.
Cleveland Crane & Car Co., Wickliffe, O.
Whiting Foundry Equipment Co., Harvey, Ill.
Yale and Towne Mfg. Co., New York.

HOISTS, MAGNETIC.

Electric Controller and Mfg. Co., Cleveland, O.

HUMIDIFYING.

Carrier Air Conditioning Co., New York.

HUMIDITY CONTROL, AUTOMATIC

Carrier Air Conditioning Co., New York.

HYDRAULIC MACHINERY.

Alliance Machine Co., Alliance, O.

INJECTORS.

Detroit Lubricator Co., Detroit, Mich.
Manning, Maxwell & Moore, New York.

LATHES.

Jones & Lamson Machine Co., Springfield, Vt.
Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.
Warner & Swasey Co., Cleveland, O.

LATHES, BENCH.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, CHUCKING.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, TURRET.

Jones & Lamson Machine Co., Springfield, Vt.
Warner and Swasey Co., Cleveland, O.

LATHES, FOOT POWER.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, ENGINE.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LATHES, WOOD.

Seneca Falls Mfg. Co., Seneca Falls, N. Y.

LOCOMOTIVE—COALING STATIONS

Dodge Co., J. M., Philadelphia, Pa.

LOCOMOTIVES, ELECTRIC.

Jeffrey Mfg. Co., Columbus, O.

LUBRICANTS.

Dixon Crucible Co., Jos., Jersey City, N. J.

LUBRICATORS.

Detroit Lubricator Co., Detroit, Mich.

MACHINERY DEALERS.

Manning, Maxwell & Moore, New York.

MAGNETS, LIFTING.

Electric Controller and Mfg. Co., Cleveland, O.

MANDRELS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

METAL, ANTI-FRICTION.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METALS, BEARING.

Allan & Son, A., New York.
Dodge Mfg. Co., Mishawaka, Ind.

METERS, VENTURI.

Builders Iron Foundry, Providence, R. I.

METERS, WATER.

National Meter Co., New York.

MILLING MACHINES.

Manning, Maxwell & Moore, New York.

MOTORS, ELECTRIC.

American Engine Co., Bound Brook, N. J.
General Electric Co., Schenectady, N. Y.
Ridgway Dynamo & Engine Co., Ridgway, Pa.

OILING DEVICES.

Detroit Lubricator Co., Detroit, Mich.

PIPE CUTTING AND THREADING MACHINES.

Manning, Maxwell & Moore, New York.

PRESSES, HYDRAULIC.

Alliance Machine Co., Alliance, O.

PISTONS, METAL FOR FACING.

Allan & Son, A., New York.

PAPER MILL MACHINERY.

Sandusky Foundry & Machine Co., Sandusky, O.

PLANERS, METAL.

Manning, Maxwell & Moore, New York.

PULLEYS.

Dodge Mfg. Co., Mishawaka, Ind.
National Brake and Clutch Co., Boston, Mass.

PUMPS, CENTRIFUGAL.

Jeanesville Iron Works Co., Hazleton, Pa.
Morris Machine Works, Baldwinsville, N .Y.
Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, GAS DRIVEN.

Riverside Engine Co., Oil City, Pa.

PUMPS, VACUUM.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, PRESSURE.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

PUMPS, TURBINE.

Kerr Turbine Co., Wellsville, N. J.

PUNCHES AND SHEARS.

Alliance Machine Co., Alliance, O.
Manning, Maxwell & Moore, New York.

REAMERS.

Morse Twist Drill & Machine Co., New Bedford, Mass.

REGULATORS, FEED WATER.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

RIVET HEADERS.

National Machinery Co., Tiffin, O.

RIVETERS, HYDRAULIC.

Alliance Machine Co., Alliance, O.

ROLLING MILL MACHINERY.

Alliance Machine Co., Alliance, O.

SCREW PLATES.

Carpenter Tap & Die Co., J. M., Pawtucket. R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

SEPARATORS, STEAM AND OIL.

Albany Steam Trap Co., Albany, N. Y.
Lindstrom, John T., Allentown, Pa.

SHAPERS.

Manning, Maxwell & Moore, New York.

SMOKELESS FURNACE.

Detroit Stoker & Foundry Co., Detroit, Mich.

SOCKETS AND SLEEVES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

SPROCKETS.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Link Belt Co., Philadelphia, Pa.

STEEL PLATE CONSTRUCTION.

Robb-Mumford Boiler Co., South Framingham, Mass.
Struthers-Wells Co., Warren, Pa.

STOKERS, MECHANICAL.

Detroit Stoker & Foundry Co., Detroit, Mich

SUPERHEATERS.

Heine Safety Boiler Co., St. Louis, Mo.

TAPPING MACHINES AND ATTACHMENTS.

F. A. Errington, New York.

TAPS AND DIES.

Carpenter Tap & Die Co., J. M., Pawtucket, R. I.
Morse Twist Drill & Machine Co., New Bedford, Mass.

TELPHERS.

Dodge Co., J. M., Philadelphia, Pa.

TOWERS, HOISTING.

Dodge Co., J. M., Philadelphia, Pa.

TRACK, INDUSTRIAL.

Whiting Foundry Equipment Co., Harvey, Ill.

TRAMWAYS, BRIDGE.

Dodge Co. J. M., Philadelphia, Pa.

TRAPS, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Lindstrom, John T., Allentown, Pa.

TRANSMISSION MACHINERY.

Diamond Chain & Mfg. Co., Indianapolis, Ind.
Dodge Mfg. Co., Mishawaka, Ind.
Link Belt Co., Philadelphia, Pa.
Link Chain Belt Co., New York.

TRIPLEX BLOCKS

Yale and Towne Mfg. Co.

TURBINES, STEAM.

General Electric Co., Schenectady, N. Y.
Hoover, Owens & Rentschler Co., Hamilton, O.
Kerr Turbine Co., Wellsville, N. Y.

TURRET LATHES.

Jones & Lamson Machine Co., Springfield, Vt
Warner & Swasey Co., Cleveland, O.

UPSETTING AND FORGING MACHINES.

National Machinery Co., Tiffin, O.

VALVE DISCS, METALLIC.

Allan & Son, A., New York.

VALVES, AUTOMATIC.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BACK PRESSURE.

Kennedy Valve Co., Elmira, N. Y.
Walch & Wyeth, Chicago, Ill.

VALVES, BOILER STOP.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, BLOW-OFF.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Manning, Maxwell & Moore, New York.

VALVES, CHECK.

Albany Steam Trap Co., Albany, N. Y.
Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, FLOAT.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

VALVES, GATE.

Albany Steam Trap Co., Albany, N. Y.
Kennedy Valve Co., Elmira, N. Y.
Nelson Valve Co., Philadelphia, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, GLOBE.

Albany Steam Trap Co., Albany, N. Y.
Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, HYDRAULIC.

Nelson Valve Co., Philadelphia, Pa.

VALVES, NON-RETURN.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Walch & Wyeth, Chicago, Ill.

VALVES, RADIATOR.

Detroit Lubricator Co., Detroit, Mich.
Kennedy Valve Co., Elmira, N. Y.

VALVES, REDUCING.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.
Mason Regulator Co., Boston, Mass.

VALVES, STEAM.

Albany Steam Trap Co., Albany, N. Y.
Manning, Maxwell & Moore, New York.
Nelson Valve Co., Philadelphia, Pa.

VALVES, SWING GATE.

Walch & Wyeth, Chicago, Ill.

WATER COOLING TOWERS.

Wheeler Mfg. Co., C. H., Philadelphia, Pa.

WATER TOWERS.

Struthers-Wells Co., Warren, Pa.

WATER COLUMNS.

Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

WATER SOFTENERS AND PURIFIERS.

Dodge Mfg. Co., Mishawaka, Ind.

WHEELS, SHEAVE, SPROCKET, TRACTION.

Link Belt Co., Philadelphia, Pa.

WIRE NAIL MACHINES.

National Machinery Co., Tiffin, O.

WIRE ROPE.

Roebling's Sons Co., John A.

WOOD POLISHING WHEELS.

Builders Iron Foundry, Providence, R. I.

WOODWORKING MACHINERY.

Manning, Maxwell & Moore, New York.
Seneca Falls Mfg. Co., Seneca Falls, N. Y.

WRENCHES.

Morse Twist Drill & Machine Co., New Bedford, Mass.

ALPHABETICAL LIST OF ADVERTISERS